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Gonzalez Jimenez et al.

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(54) **DEVICE FOR GENERATING FREQUENCY-STABLE SIGNALS WITH SWITCHABLE INJECTION-LOCKED OSCILLATOR**

(71) Applicant: **Commissariat a l'energie atomique et aux energies alternatives**, Paris (FR)

(72) Inventors: **Jose-Luis Gonzalez Jimenez**, Voreppe (FR); **Alexandre Siligaris**, Grenoble (FR)

(73) Assignee: **Commissariat a l'energie atomique et aux energies alternatives**, Paris (FR)

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H03B 5/12 (2006.01)
H03B 21/02 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H03L 7/083*** (2013.01); ***H03B 5/1212*** (2013.01); ***H03B 5/1215*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC .. H03B 5/1228; H03B 5/1265; H03B 21/00; H03B 21/01; H03B 21/02; H03B 2200/0074; H03L 7/16; H03L 7/18; H03L 7/24; H04L 7/033
USPC 331/18
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,852,603 A 12/1998 Lehtinen et al.
6,867,656 B2 * 3/2005 Hajimiri H03B 27/00 327/118

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1 931 033 A2 6/2008

OTHER PUBLICATIONS

International Search Report Issued Jun. 17, 2014 for PCT/EP2014/060362 filed May 20, 2014.

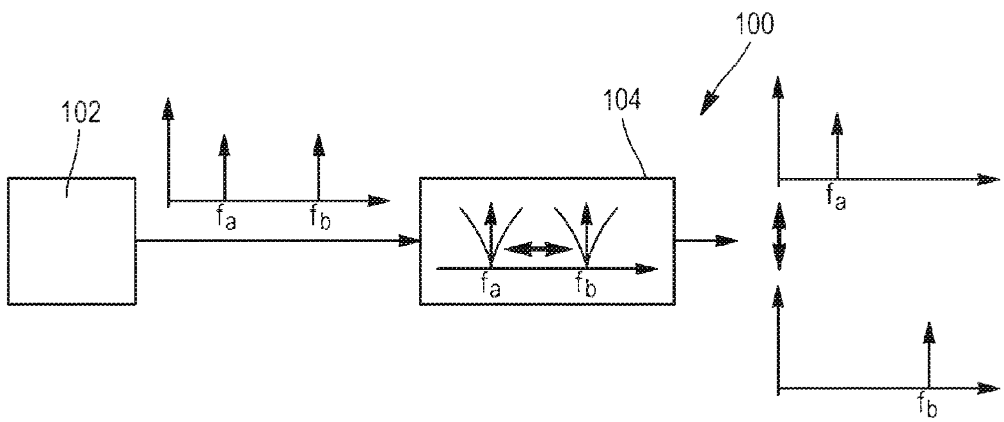
(Continued)

Primary Examiner — Levi Gannon
(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

A device for generating at least one frequency-stable periodical signal, including: a generator configured to generate at least one first periodical signal with frequency spectrum that includes at least two lines at different frequencies f_a and f_b; a first switchable injection-locked oscillator configured to receive at an input the first periodical signal and to be locked, in a first state, to the frequency f_a, and in a second state, to the frequency f_b, as a function of a value of at least one control signal applied at the input of the first switchable injection-locked oscillator.

13 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

H03L 7/18	(2006.01)
H03L 7/24	(2006.01)
H03L 7/083	(2006.01)
H03L 7/099	(2006.01)
H04L 7/033	(2006.01)

(52) **U.S. Cl.**

CPC ***H03B 5/1228*** (2013.01); ***H03B 5/1265*** (2013.01); ***H03B 21/02*** (2013.01); ***H03L 7/099*** (2013.01); ***H03L 7/18*** (2013.01); ***H03L 7/24*** (2013.01); ***H04L 7/033*** (2013.01); *H03B 2200/0074* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,577,305	B1 *	11/2013	Rossi	H04B 7/0413 327/115
8,976,901	B2 *	3/2015	Diao	H04L 27/20 375/295
9,231,596	B2 *	1/2016	Chen	H03B 5/1215
2008/0139150	A1	6/2008	Li et al.	
2008/0285625	A1	11/2008	Chang et al.	
2009/0027091	A1 *	1/2009	Yamaguchi	H03K 27/00 327/118
2009/0085682	A1 *	4/2009	Jang	H03B 19/14 331/117 FE
2009/0102565	A1 *	4/2009	Jang	H03B 19/14 331/40
2010/0277207	A1 *	11/2010	Mahdavi	H03B 19/14 327/118
2010/0301955	A1 *	12/2010	Luong	H03B 19/00 331/117 FE
2011/0006850	A1 *	1/2011	Shibasaki	H03L 7/0805 331/55
2011/0103526	A1	5/2011	Li et al.	
2012/0161827	A1	6/2012	Madeira et al.	
2012/0274409	A1 *	11/2012	Eldesouki	H03B 5/1228 331/109
2013/0141178	A1 *	6/2013	Soe	H03B 5/1228 331/117 FE
2014/0266480	A1 *	9/2014	Li	H03B 5/1228 331/117 FE

OTHER PUBLICATIONS

French Search Report Issued Feb. 18, 2014 for FR1354754 filed May 27, 2013.

Yang, et al.. "A 7 mW 2.5 GHz Spread Spectrum Clock Generator using Switch-Controlled Injection-Locked Oscillator," Circuits and Systems (ISCAS), 2013 IEEE International Symposium, pp. 1392-1395, XP032446188.

Katz, et al., "A fully integrated SiGe E-BAND transceiver chipset for broadband point-to-point communication," Radio and Wireless Symposium (RWS), 2012 IEEE, pp. 431-434.

Richard, el al., "A 17.5-to-20.94GHz and 35-to-41.88GHz PLL in 65nm CMOS for wireless HD applications," Solid-State Circuits Conference Digest of Technical Papers (ISSCC), 2010 IEEE international, pp. 252-253.

Tiebout et al., "A 50 GHz direct injection locked oscillator topology as low power frequency divider in 0.13 um CMOS," Solid-State Circuits Conference, 2003 ESSCIRC, pp. 73-76.

Siligaris, el al., "A 60 GHz UWB Impulse Radio Transmitter with Integrated Antenna in CMOS65nm SOI Technology," Silicon Monolithic Integrated Circuits in RF Systems (SiRF), 2011 IEEE, pp. 153-156.

* cited by examiner

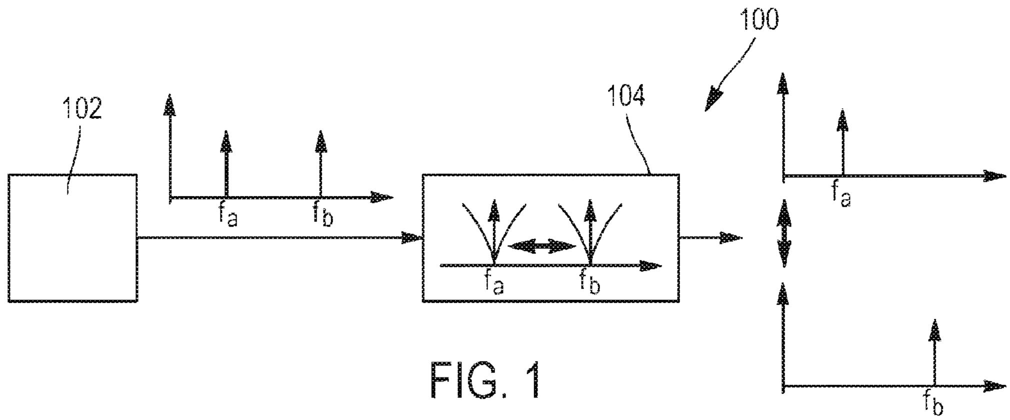


FIG. 1

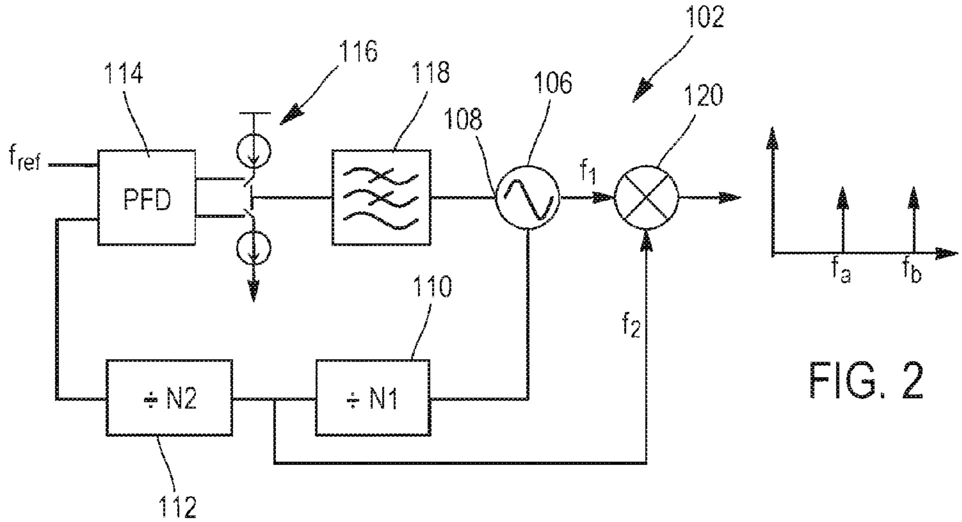


FIG. 2

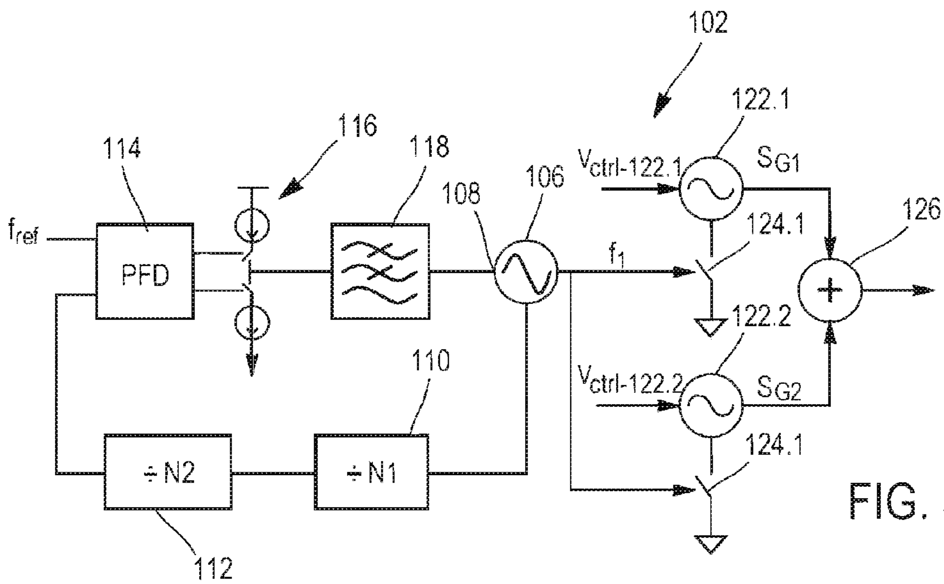


FIG. 3

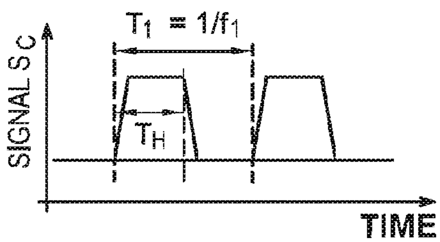


FIG. 4A

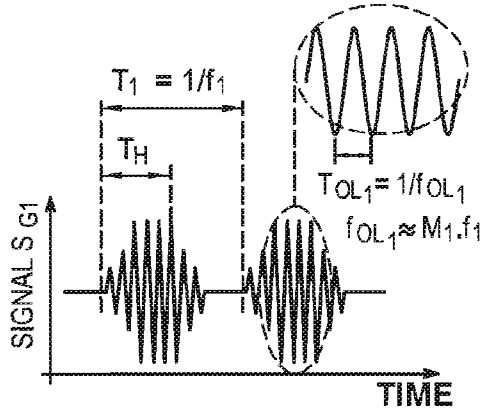


FIG. 5A

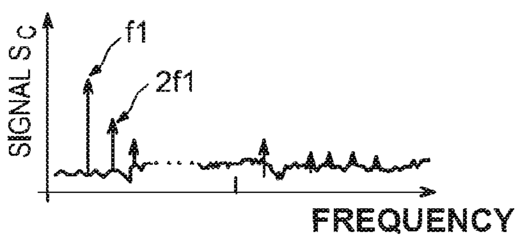


FIG.4B

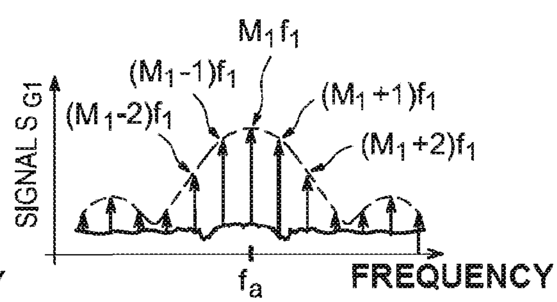


FIG. 5B

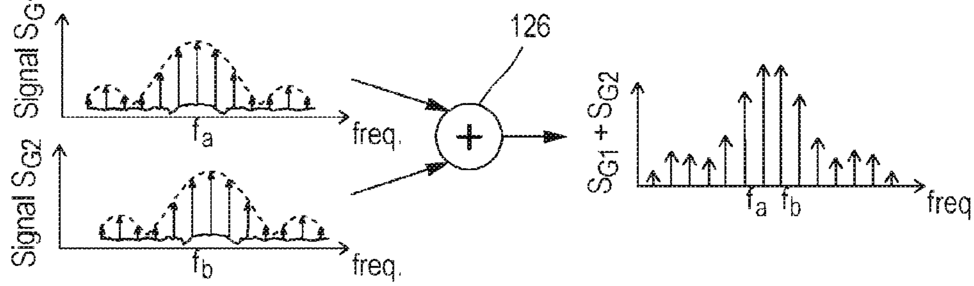


FIG. 6

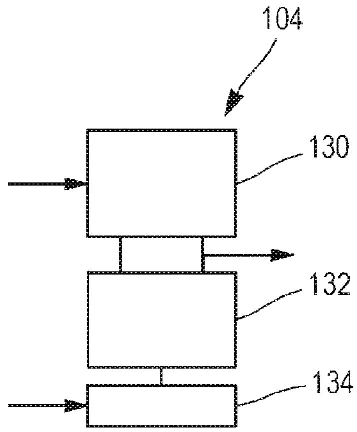


FIG. 7

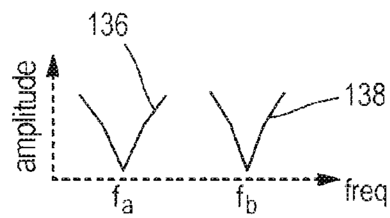


FIG. 8

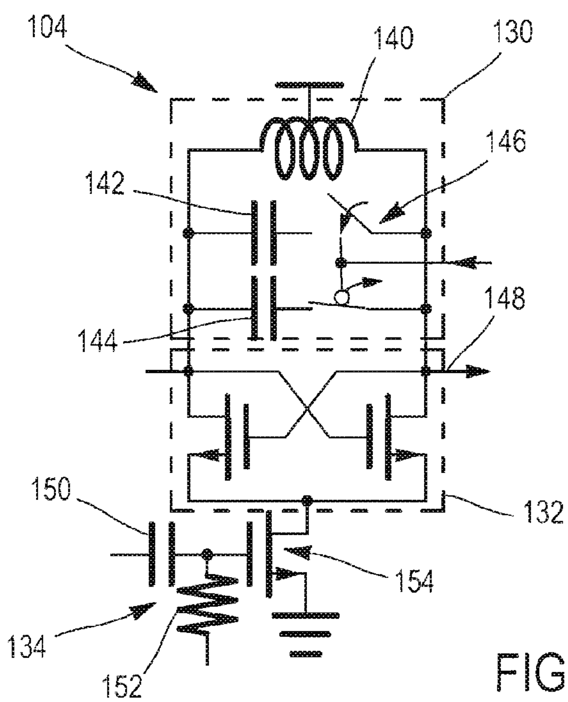


FIG. 9

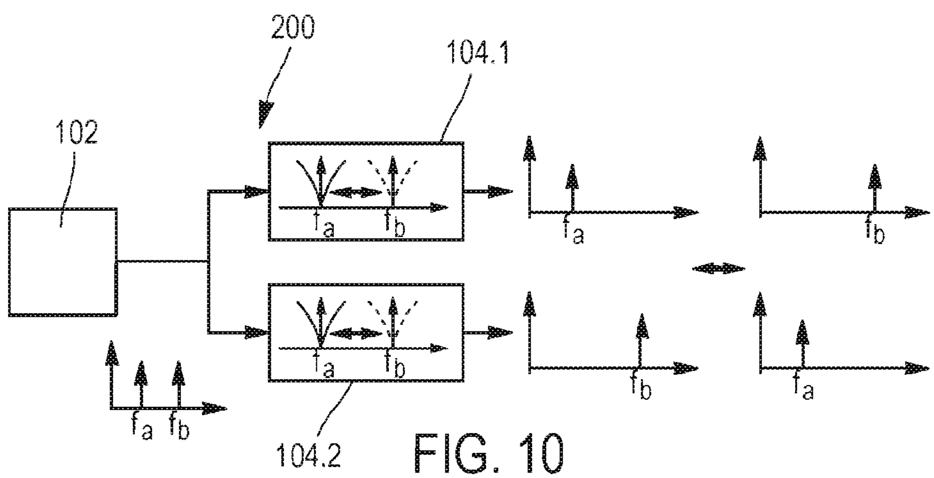


FIG. 10

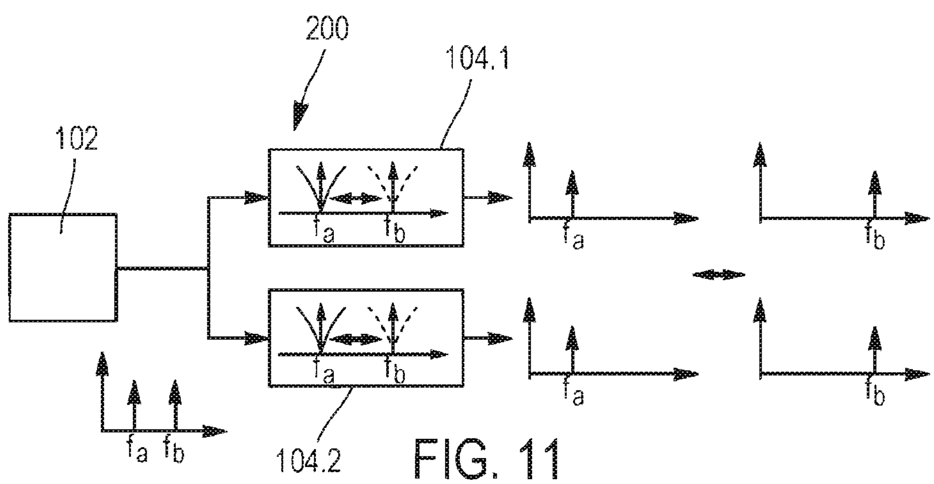


FIG. 11

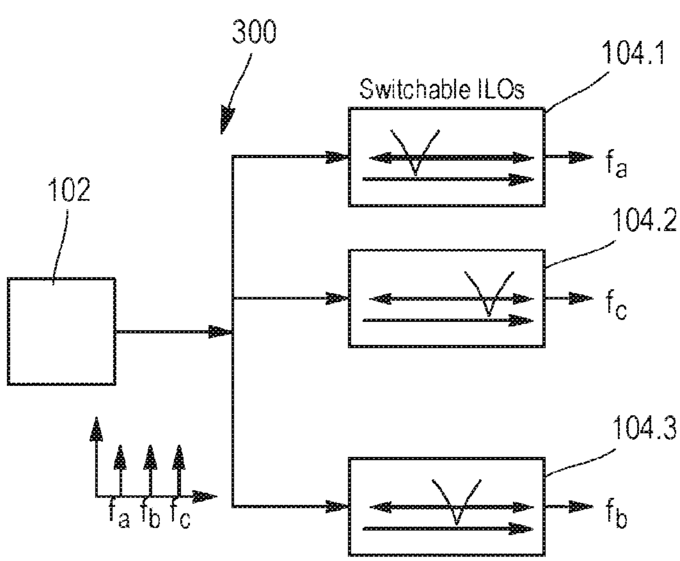


FIG. 12

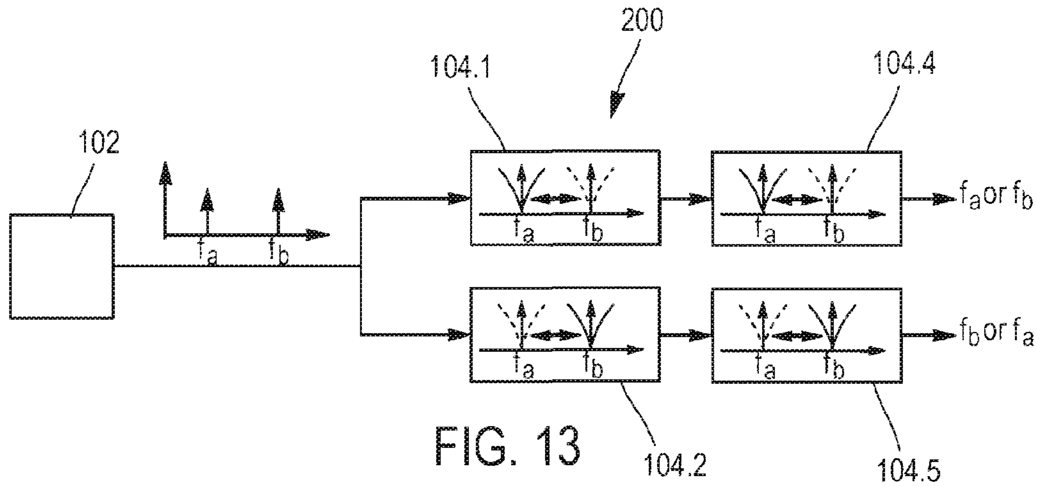


FIG. 13

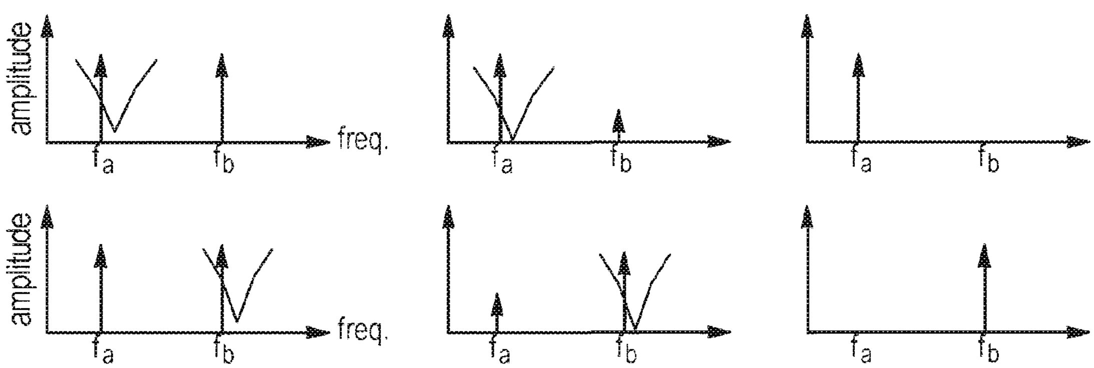


FIG. 14A FIG. 14B FIG. 14C

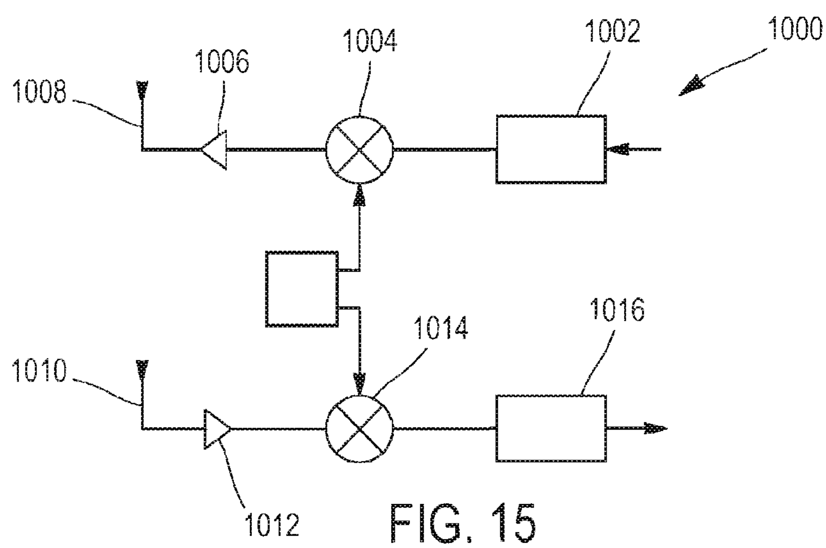


FIG. 15

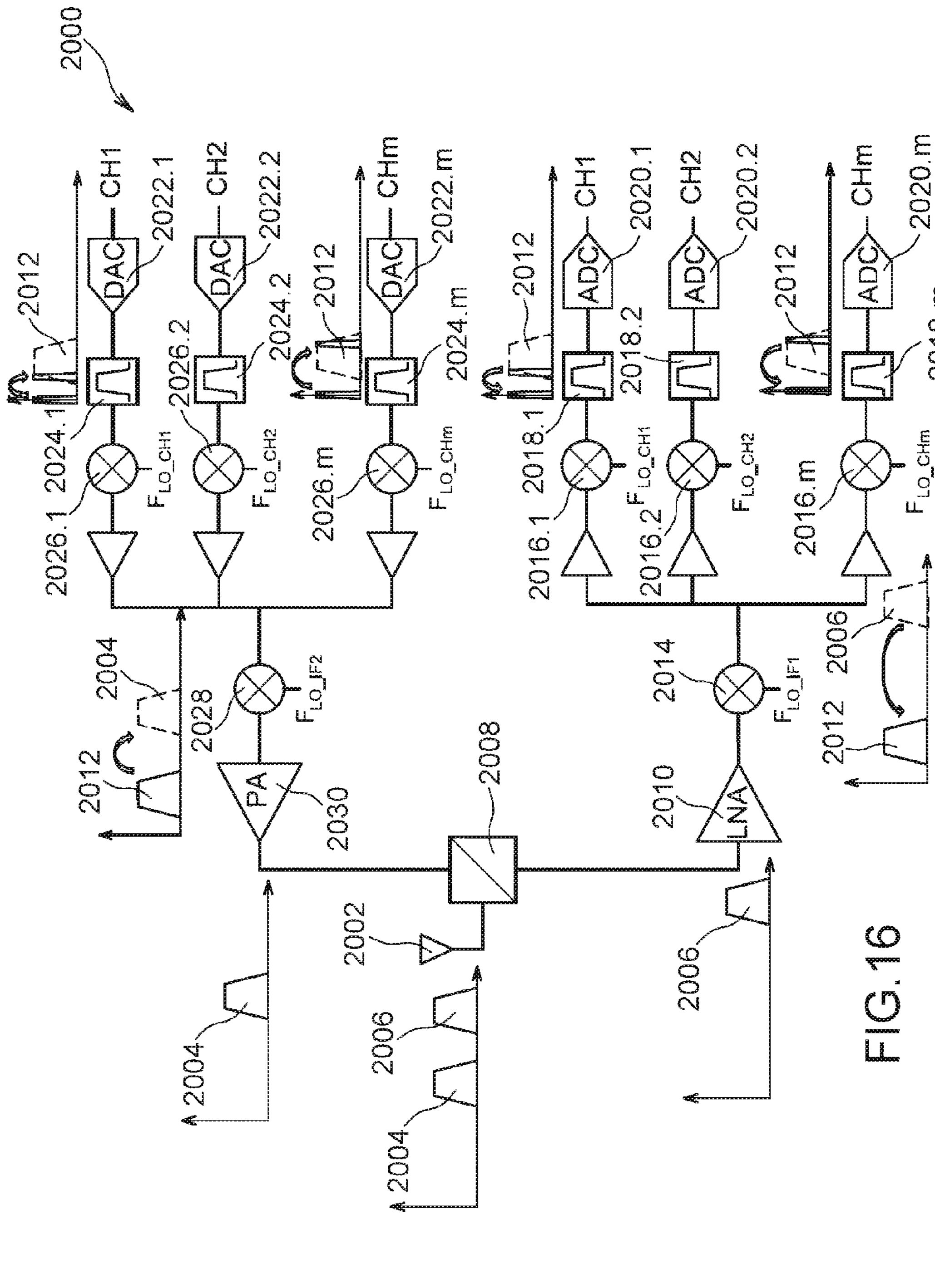

2000
DAC
DAC
DAC
ADC
ADC
ADC
CH1
CH2
CHm
CH1
CH2
CHm
2022.1
2022.2
2022.m
2020.1
2020.2
2020.m
2024.1
2024.2
2024.m
2018.1
2018.2
2018.m
2026.1
2026.2
2026.m
2016.1
2016.2
2016.m
F_{LO_CH1}
F_{LO_CH2}
F_{LO_CHm}
F_{LO_IF2}
F_{LO_IF1}
2012
2004
2006
2028
2014
PA
2030
LNA
2010
2008
2002

FIG.16

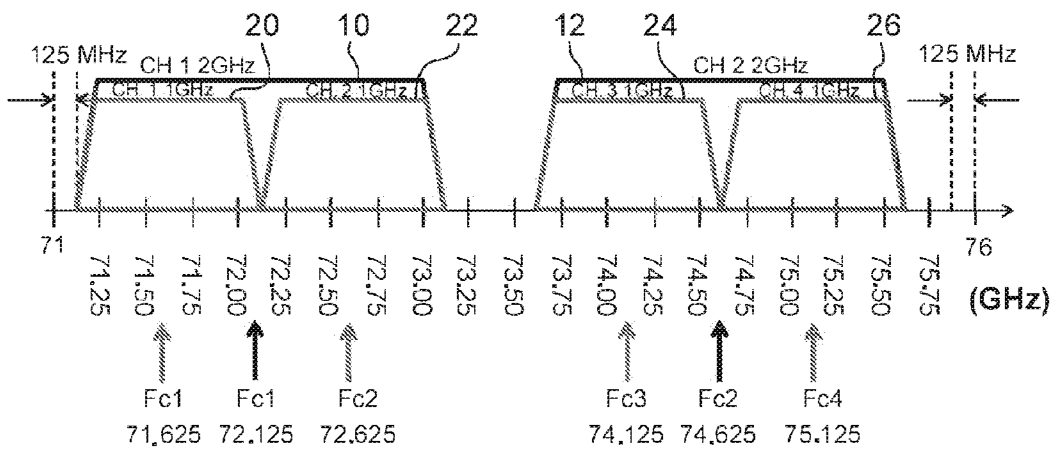

20
10
22
12
24
26
125 MHz
CH 1 2GHz
CH 1 1GHz
CH 2 1GHz
CH 2 2GHz
CH 3 1GHz
CH 4 1GHz
125 MHz
71
71.25
71.50
71.75
72.00
72.25
72.50
72.75
73.00
73.25
73.50
73.75
74.00
74.25
74.50
74.75
75.00
75.25
75.50
75.75
76
(GHz)
Fc1 71.625
Fc1 72.125
Fc2 72.625
Fc3 74.125
Fc2 74.625
Fc4 75.125

FIG.17

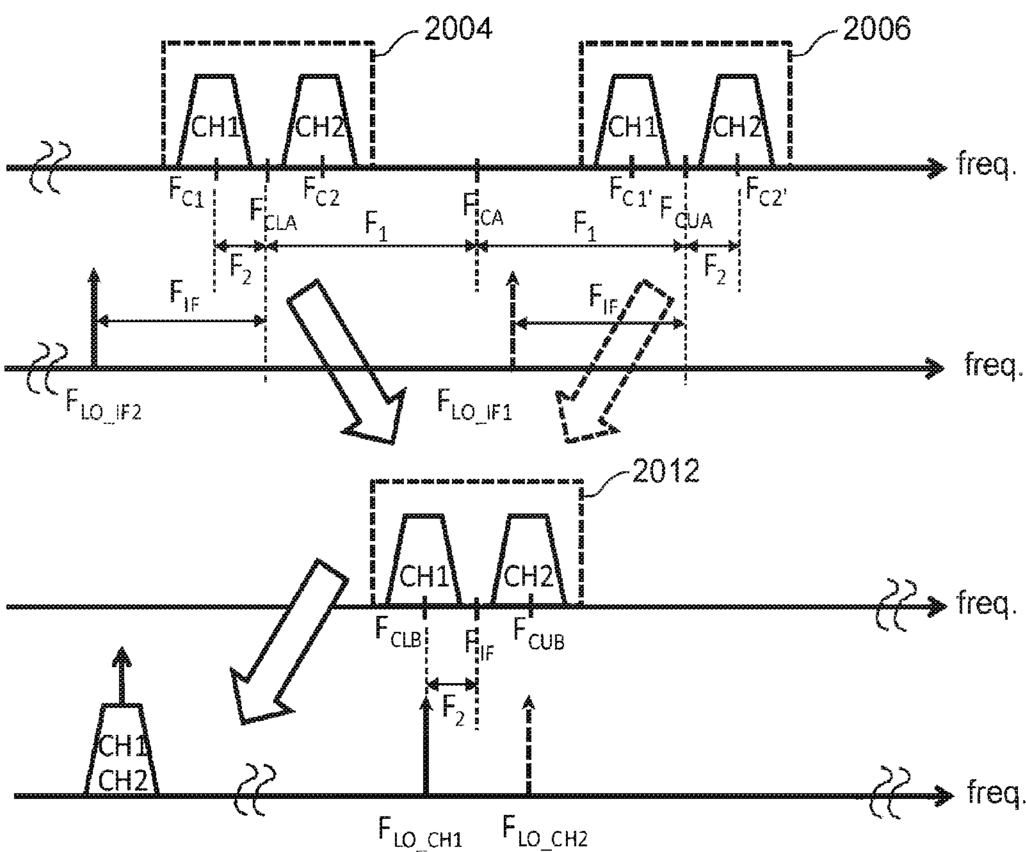

2004
2006
CH1
CH2
CH1
CH2
freq.
F_{C1}
F_{CLA}
F_{C2}
F_{CA}
$F_{C1'}$
F_{CUA}
$F_{C2'}$
F_1
F_1
F_2
F_2
F_{IF}
F_{IF}
freq.
F_{LO_IF2}
F_{LO_IF1}
2012
CH1
CH2
freq.
F_{CLB}
F_{IF}
F_{CUB}
F_2
CH1
CH2
freq.
F_{LO_CH1}
F_{LO_CH2}

FIG.18

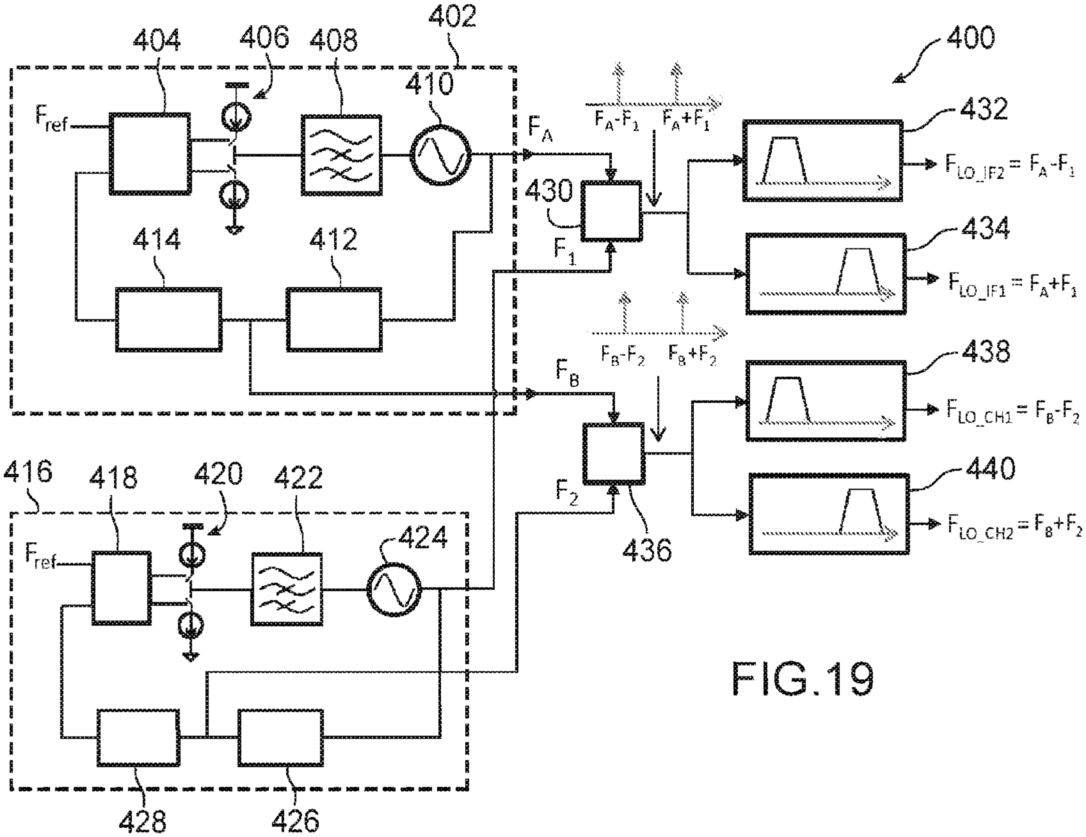


FIG.19

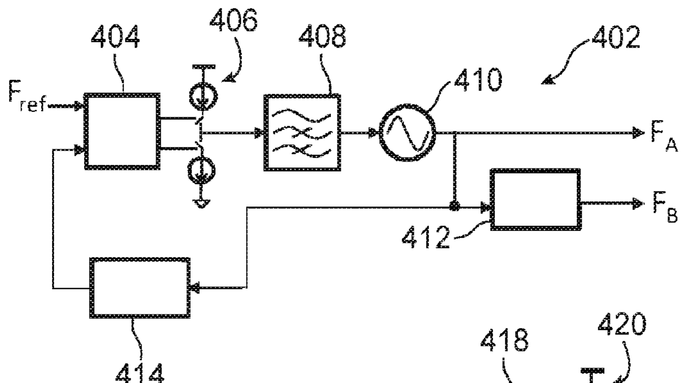


FIG.20

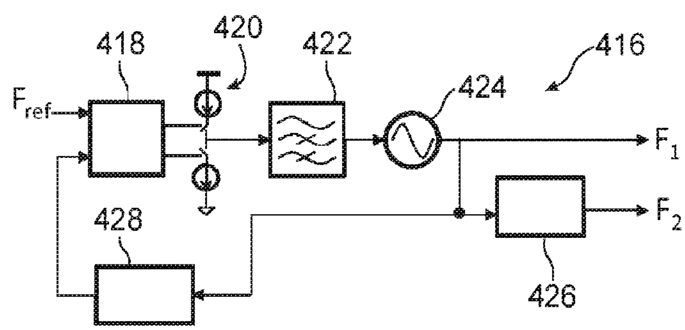


FIG.21

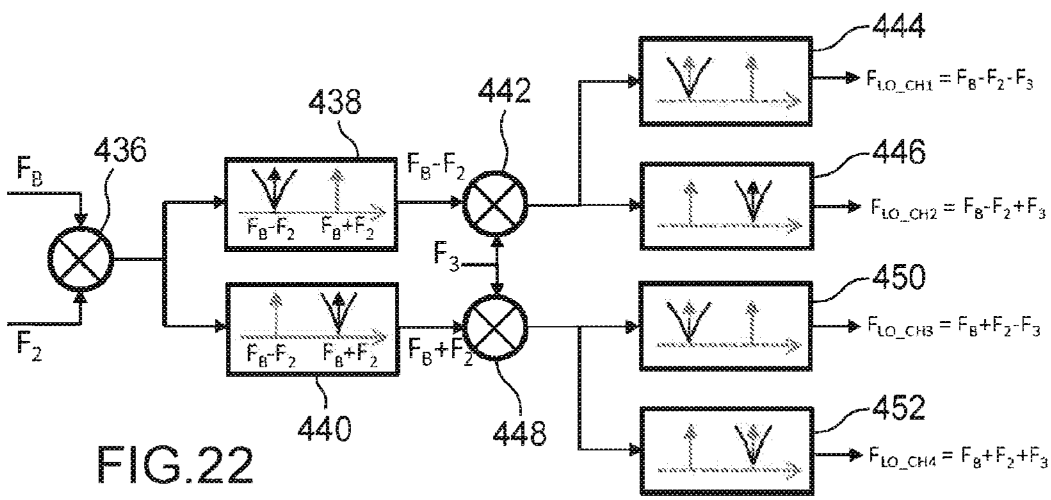


FIG.22

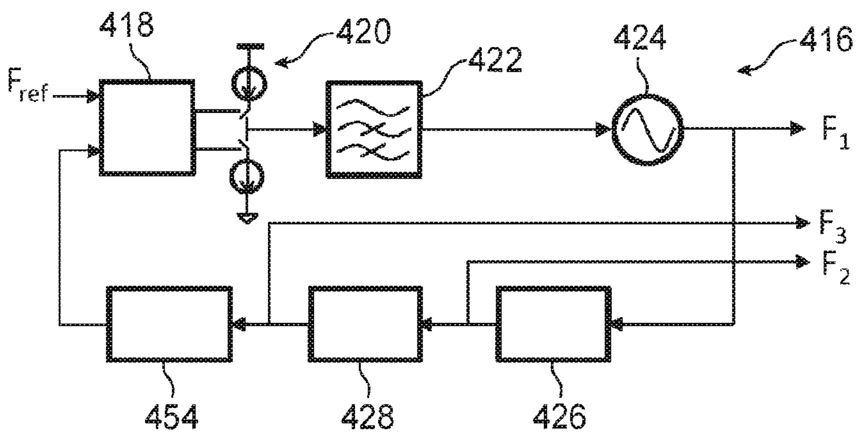


FIG.23A

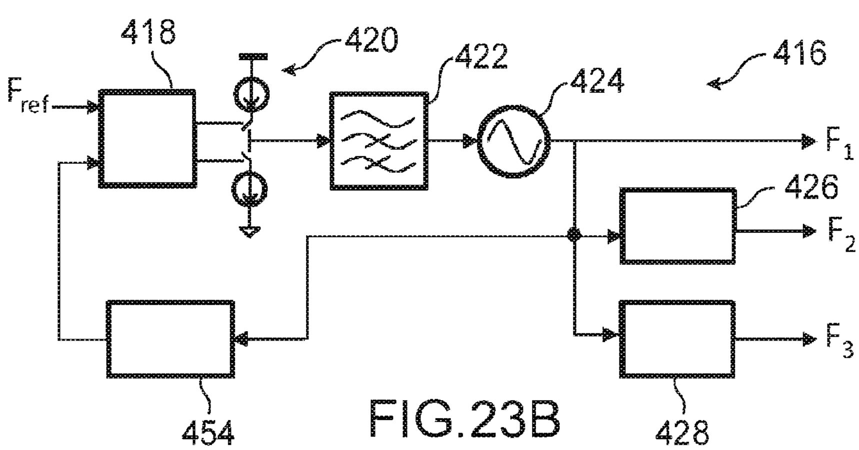


FIG.23B

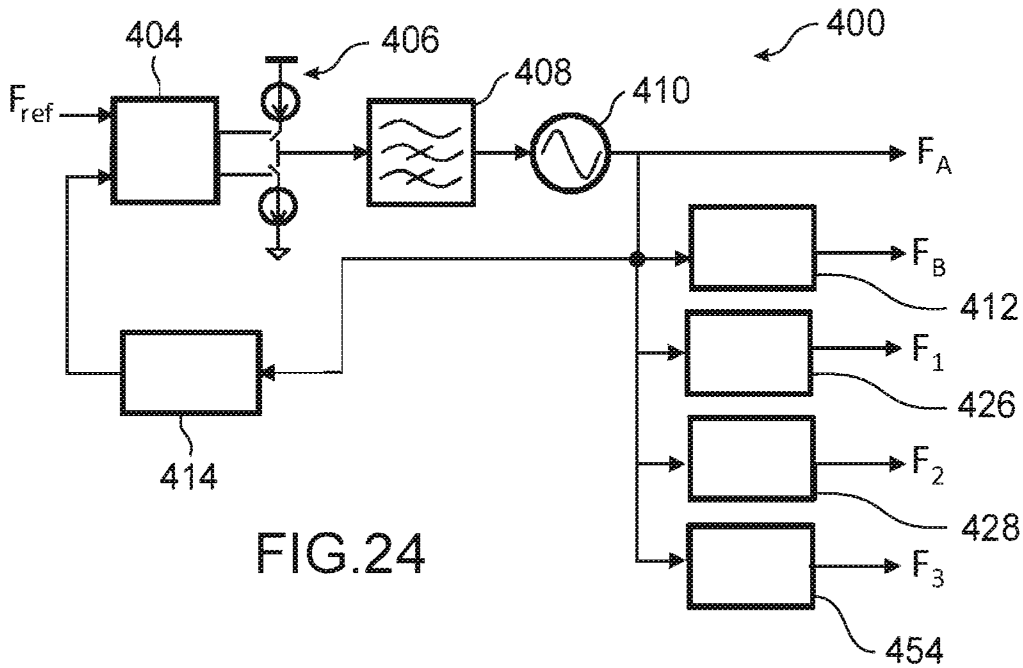

400
404
406
408
410
F_{ref}
F_A
F_B
412
F_1
426
F_2
428
F_3
454
414

FIG.24

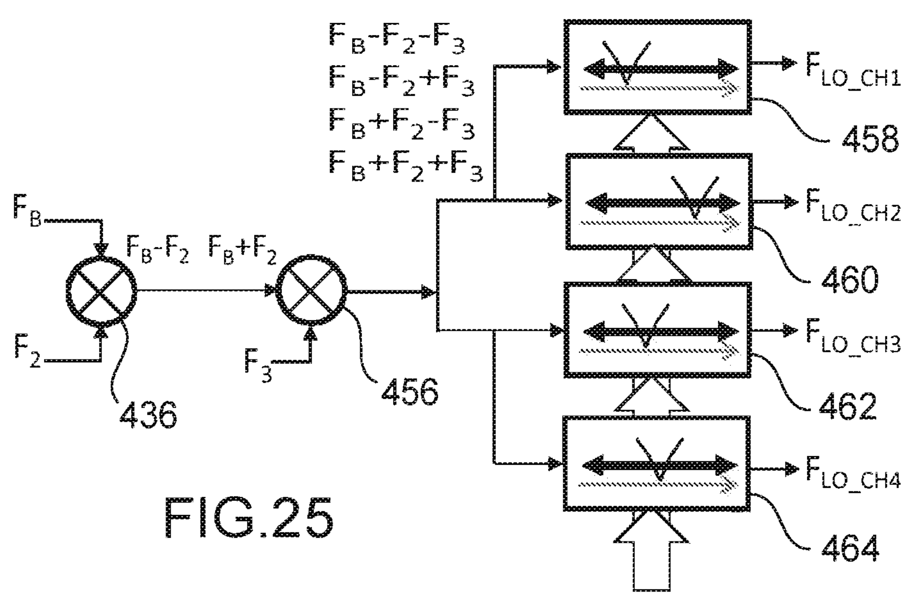

F_B-F_2-F_3
F_B-F_2+F_3
F_B+F_2-F_3
F_B+F_2+F_3
F_B
F_B-F_2 F_B+F_2
F_2
436
F_3
456
F_{LO_CH1}
458
F_{LO_CH2}
460
F_{LO_CH3}
462
F_{LO_CH4}
464

FIG.25

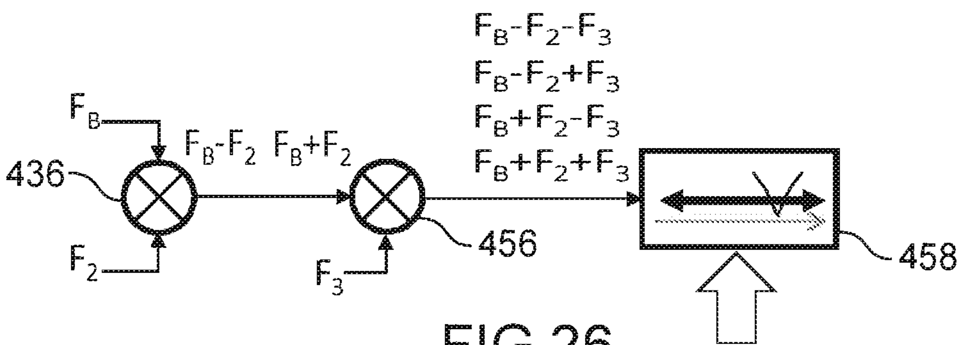

$F_B-F_2-F_3$
$F_B-F_2+F_3$
$F_B+F_2-F_3$
$F_B+F_2+F_3$
F_B
F_B-F_2 F_B+F_2
436
F_2
F_3
456
458

FIG.26

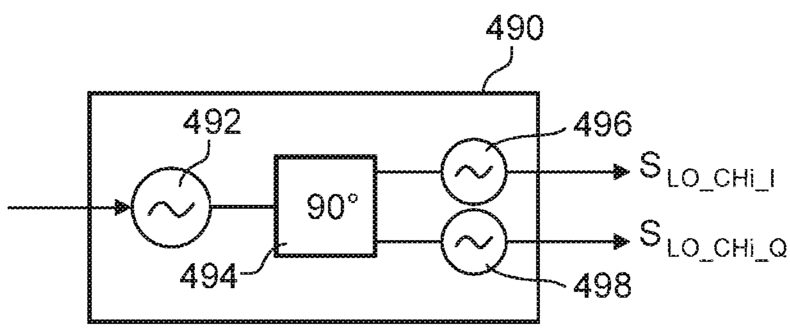

490
492
496
90°
$S_{LO\_CHi\_I}$
$S_{LO\_CHi\_Q}$
494
498

FIG.27

DEVICE FOR GENERATING FREQUENCY-STABLE SIGNALS WITH SWITCHABLE INJECTION-LOCKED OSCILLATOR

TECHNICAL FIELD

The invention relates to the field of devices for generating frequency-stable signals, used for example within transceiver devices, and in particular in wireless integrated RF transceiver devices involving several frequency-stable signals in the transmitting and receiving parts of these devices, for example for simultaneously performing transmission and reception of signals in at least two different frequency bands.

The invention is advantageously used in FDD ("Frequency Division Duplexing") type transceiver devices for example suitable for the E-Band communication standard.

STATE OF PRIOR ART

Some transceiver devices involve several frequency-stable signals for simultaneously performing transmission and reception of signals. When the transmission is to be made in a first frequency band and the reception is to be made in a second frequency band different from the first band, such a device generally includes two distinct signal generators each enabling a frequency-stable signal suitable for transmission or reception in the corresponding frequency bands to be generated, both generated signals being of different frequencies.

Moreover, it can be necessary, for some communication standards, to be able to switch over the transmission and reception frequency bands, which requires either to be able to output each of the generated signals to the transmitting and receiving parts of the device, or to be able to quickly change the frequency values of the generated signals.

For example, in the case of an "E-Band" type transceiver device, two frequency bands of 5 GHz around 70 GHz and 80 GHz are used for transmitting and receiving signals. Furthermore, such a device should be able to switch over both these frequency bands for transmission and reception.

Document of O. Katz et al., "A fully integrated SiGe E-BAND transceiver chipset for broadband point-to-point communication", Radio and Wireless Symposium (RWS), 2012 IEEE, pages 431-434, 15-18 Jan. 2012, describes an FDD type transceiver device suitable for the E-Band communication standard. To be able to simultaneously perform transmission and reception of signals in both different frequency bands and to be able to switch over both these bands, two PLL type distinct signal generators are used, and a device for switching over sending the output signals of both these generators in the transmitting and receiving parts is used.

Involving two distinct signal generators is an expensive, bulky solution which consumes a lot of electric energy. Moreover, in such a device, the duration for performing switching over of the transmission and reception frequency bands depends on the locking duration of the PLL, wherein this duration can be too long for some applications.

DISCLOSURE OF THE INVENTION

One purpose of the present invention is to provide a new type of device enabling at least one frequency-stable output signal to be generated and a change in the value of the frequency of the output signal to be readily and quickly

made, and which does not have at least part of the drawbacks on the devices of the prior art.

For this, the present invention provides a device for generating at least one frequency-stable periodical signal, including at least:

- a generator able to generate at least one first periodical signal the frequency spectrum of which includes at least two lines, or peaks, at the different frequencies f_a and f_b;
- a first switchable injection-locked oscillator able to receive at the input the first periodical signal and to be locked, in a first state, to the frequency f_a, and in a second state, to the frequency f_b, as a function of the value of at least one control signal applied at the input to the first switchable injection-locked oscillator.

The device according to the invention involves the locking proprieties of the injection-locked oscillator to one the frequencies of the signal applied at the input of this oscillator. The switchable injection-locked oscillator is used as a switchable band-pass filter applied to the first periodical signal the frequency spectrum of which includes at least two lines at different frequencies, thus corresponding to a multi-tone signal. Depending on the configuration, or on the switching state, wherein the switchable injection-locked oscillator is, the output signal of the device then includes only one of both these frequencies. Therefore, it is not necessary to involve two distinct devices to generate signals in two different frequency bands.

Moreover, the locking switching to either frequency of the injection-locked oscillator is quicker than for devices of prior art which require, at each frequency change, locking a PLL to the new frequency.

The lines at the frequencies f_a and f_b may have substantially similar amplitudes and/or be in phase with each other and/or correspond to two main lines of the frequency spectrum of the first periodical signal. Lines with similar amplitudes and/or in phase with each other enable the frequency-stable periodical signal generated to have a substantially constant amplitude and/or phase regardless of the frequency to which the oscillator is locked. The switches of the oscillator do not modify in this case the amplitude and/or phase of the output signal. The lines at the frequency f_a and f_b corresponding to main lines of the frequency spectrum of the first periodical signal facilitates locking the switchable oscillator to either line and avoids a locking of the oscillator to a possible other line of the frequency spectrum of the first periodical signal.

The characteristic according to which the lines at the frequencies f_a and f_b have substantially similar amplitudes may correspond to a difference in voltage of about 4 dB maximum between these amplitudes.

The first switchable injection-locked oscillator may include at least:

- a resonating structure able to generate a second periodical signal oscillating, in the first state, at a first free oscillation frequency, for example close or substantially equal to f_a, and in the second state, at a second oscillation frequency, for example close or substantially equal to f_b, with a value different from that of the first free oscillation frequency;
- an electrical element electrically coupled to the resonating structure and an impedance of which is equivalent to that of a negative electrical resistance;
- an injection circuit electrically coupled to said electrical element, receiving at the input the first periodical signal

and able to provide said electrical element with a current with a frequency equal to that of the first periodical signal.

In this case, the resonating structure of the first switchable injection-locked oscillator may include at least one LC resonating structure comprising the following components:

an inductor coupled in parallel, in the first state, to a first capacitor or, in the second state, to a second capacitor having an electric capacitance with a value different from that of the first capacitor, or

a capacitor coupled in parallel, in the first state, to a first inductor or, in the second state, to a second inductor with a value different from that of the first inductor, or

in the first state, a first inductor coupled in parallel with a first capacitor or, in the second state, a second inductor coupled in parallel to a second capacitor, the first inductor having a value different from that of the second inductor and the first capacitor having an electric capacitance with a value different from that of the second capacitor,

and may further include switching elements able to modify the couplings of the components of the LC resonating circuit as a function of the control signal.

The electrical element of the first switchable injection-locked oscillator may include an MOS type differential twisted pair, and for example formed by two NMOS type transistors.

The injection circuit of the first switchable injection-locked oscillator may include at least:

a capacitor including a first terminal to which the first periodical signal is intended to be applied;

a resistor including a first terminal to which a DC bias voltage is intended to be applied and a second terminal electrically connected to a second terminal of the capacitor;

an MOS transistor a gate of which is electrically connected to the second terminal of the capacitor and a drain of which is electrically connected to the electrical element of the switchable injection locked oscillator.

The generator may include:

a phase-locked loop outputting a third periodical signal with a frequency f_1 and a fourth periodical signal with a frequency $f_2=f_1/N_1$, with N_1 higher than 1;

a frequency mixer receiving at the input the third periodical signal and the fourth periodical signal and outputting the first periodical signal such that $f_a=f_1-f_2$ and $f_b=f_1+f_2$.

Such a generator is cheaper, less bulky and consumes less energy than two PLL used for generating two signals with different frequencies.

Alternatively, the generator may include:

a phase-locked loop outputting a third periodical signal with a frequency f_1;

means able to receive at the input the periodical signal with a frequency f_1 and to generate at least two signals S_{G1} and S_{G2} in phase with each other and each corresponding to a train of oscillations with a frequency substantially equal to f_a and f_b respectively, with a duration lower than $T_1=1/f_1$ and periodically repeated at the frequency f_1,

an adder able to output the first periodical signal corresponding to the sum of the signals S_{G1} and S_{G2}.

Such a generator is generally cheaper, less bulky and consumes less energy than two PLL used for generating two signals with different frequencies.

Said means of the generator may include at least two voltage controlled oscillators the free oscillation ranges of which include the frequencies f_a and f_b respectively, and at least two switches connected at power supply inputs of the voltage controlled oscillators and able to be controlled by the periodical signal with the frequency f_1 such that they generate non-zero supply voltages of the voltage controlled oscillators only for part of each period T_1 or at least two switches connected to outputs of the voltage controlled oscillators and able to be controlled by the periodical signal with the frequency f_1 such that they break electrical connections between the outputs of the voltage controlled oscillators and inputs of the adder for part of each period T_1. The advantage of the configuration in which the switches are connected to the power supply inputs of the voltage controlled oscillators is to not permanently operate the oscillators at a high frequency, and thus to reduce the energy consumption of the voltage controlled oscillators.

The device may further include at least one second switchable injection locked oscillator able to receive at the input the first periodical signal and to be locked in a first state to the frequency f_b and in a second state to the frequency f_a, or to be locked in the first state to the frequency f_a and in the second state to the frequency f_b, as a function of the control signal applied at the input of the first and second switchable injection locked oscillators. Such a device can thus output two signals with two equal or different frequencies, and advantageously with similar powers when the lines at the frequencies f_a and f_b of the frequency spectrum of the first periodical signal have a similar amplitude and/or are in phase with each other when the lines at the frequencies f_a and f_b of the frequency spectrum of the first periodical signal are in phase with each other.

The frequency spectrum of the first periodical signal may include at least n lines with n different frequencies, the device may further include n switchable injection-locked oscillators each able to receive at the input the first periodical signal and to be locked to each of the n frequencies as a function of the value of the controlled signal applied at the input of the n switchable injection-locked oscillators, n being an integer number higher than 1.

The device may further include at least one third switchable injection-locked oscillator able to receive at the input an output signal of the first or second switchable injection-locked oscillator or one of said n switchable injection locked oscillators, and to be locked to a frequency similar to that to which the switchable injection-locked oscillator is locked (the first or the second or one of the switchable injection-locked oscillators) to which the third switchable injection-locked oscillator is connected.

The invention also relates to a device for transmitting and/or receiving signals, including at least one device for generating a frequency-stable periodical signal as previously described coupled to a modulator and/or a demodulator of the transmitting and/or receiving device. Such a device may correspond to an integrated wireless RF transceiver device, for example of the FDD and E-Band type.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood upon reading the description of exemplary embodiments given by way of purely indicative and in no way limiting purposes in reference to the appended drawings in which:

FIG. 1 schematically shows a device for generating a frequency-stable signal, object of the present invention, according to a first embodiment;

FIGS. **2** and **3** schematically show exemplary embodiments of a generator of a device for generating a frequency-stable signal, object of the present invention;

FIGS. **4**A and **4**B respectively show the waveform and the spectrum of a signal Sc obtained in a generator of a device for generating a frequency-stable signal, object of the present invention;

FIGS. **5**A and **5**B respectively show the waveform and the spectrum of a signal S_{G1} obtained in a generator of a device for generating a frequency-stable signal, object of the present invention;

FIG. **6** shows the addition of frequency spectra of the signals S_{G1} and S_{G2} made in a generator of a device for generating a frequency-stable signal, object of the present invention;

FIG. **7** schematically shows a switchable injection-locked oscillator of a device for generating a frequency-stable signal, object of the present invention;

FIG. **8** shows locking ranges of a switchable injection-locked oscillator of a device for generating a frequency-stable signal, object of the present invention;

FIG. **9** schematically shows an exemplary embodiment of a switchable injection-locked oscillator of a device for generating a frequency-stable signal, object of the present invention;

FIG. **10** schematically shows a device for generating a frequency-stable signal, object of the present invention, according to a second embodiment of the invention;

FIG. **11** schematically shows a device for generating a frequency-stable signal, object of the present invention, according to a first alternative of the second embodiment;

FIG. **12** schematically shows a device for generating a frequency-stable signal, object of the present invention, according to a third embodiment of the invention;

FIG. **13** schematically shows a device for generating a frequency-stable signal, object of the present invention, according to a second alternative of the second embodiment;

FIGS. **14**A to **14**C show frequency spectra obtained within a device for generating a frequency-stable signal, object of the present invention, according to the second alternative of the second embodiment;

FIG. **15** schematically shows a part of a transceiver device, object of the present invention;

FIG. **16** schematically shows a part of a device for transmitting and receiving signals, object of the present invention, according to a particular embodiment;

FIG. **17** shows examples of channel distribution in a transmission frequency band used in the device object of the present invention;

FIG. **18** illustrates the use of symmetries to generate the frequencies used in the device object of the present invention;

FIG. **19** shows an exemplary embodiment of a frequency synthesis device being part of a transmitting and/or receiving device, object of the present invention;

FIGS. **20** and **21** show alternative embodiments of a PLL of a frequency synthesis device being part of a transmitting and/or receiving device, object of the present invention;

FIG. **22** shows a part of a frequency synthesis device being part of a transmitting and/or receiving device, object of the present invention, enabling data to be transmitted on four channels in each of the transmission frequency bands;

FIGS. **23**A and **23**B show alternative embodiments of a PLL of a frequency synthesis device being part of a transmitting and/or receiving device, object of the present invention;

FIG. **24** shows an alternative embodiment of a PLL of a frequency synthesis device being part of a transmitting and/or receiving device, object of the present invention;

FIG. **25** shows a part of a frequency synthesis device being part of a transmitting and/or receiving device, object of the present invention, enabling data to be transmitted on four channels having variable frequencies in each of the transmission frequency bands;

FIG. **26** shows a part of a frequency synthesis device being part of a transmitting and/or receiving device, object of the present invention, enabling data to be transmitted on a channel with a variable frequency in each of the transmission frequency bands;

FIG. **27** schematically shows an exemplary embodiment of a frequency recovering circuit enabling I/Q signals with the same frequency to be outputted and used in a transmitting and/or receiving device, object of the present invention.

Identical, similar or equivalent parts of the different figures described hereinafter bear the same reference numerals so as to facilitate switching from one figure to the other.

The different parts shown in the figures are not necessarily drawn according to a uniform scale, to make them more legible.

The different possibilities (alternatives and embodiments) should be understood as being not exclusive of each other and can be combined to each other.

DETAILED DISCLOSURE OF PARTICULAR EMBODIMENTS

FIG. **1** is first referred to, which shows a device **100** for generating a frequency-stable periodical signal, and the frequency of the generated signal of which can be readily and quickly modified, according to a first embodiment.

The device **100** includes a generator **102** generating a first frequency-stable periodical signal the frequency spectrum of which includes two main lines at different frequencies, called f_a and f_b, and the values of which correspond to the values that the frequency of the signal to be generated by the device **100** can assume. Advantageously, the generator **102** is such that the two main lines of the frequency spectrum of the first periodical signal have similar or substantially similar amplitudes, or powers (with for example a difference in voltage lower than or equal to about 4 dB). The device **100** also includes a switchable injection-locked oscillator **104**, referred to as switchable ILO ("Injection-Locked Oscillator"), receiving at the input the first periodical signal.

The ILO **104** is switchable, that is includes a mechanism enabling it to modify its locking range, and thus to be locked to one of the frequencies f_a and f_b of the first periodical signal according to the configuration in which the switchable ILO **104** is. The signal obtained at the output of the switchable ILO **104**, corresponding to the output signal of the device **100**, is thus a frequency-stable periodical signal, for example a sinusoidal or substantially sinusoidal one, the frequency spectrum of which includes a single main line at the frequency f_a or f_b according to the configuration in which the switchable ILO **104** is put.

FIG. **2** shows a first exemplary embodiment of the generator **102**.

The generator **102** includes an oscillator **106**, for example of the VCO (Voltage Controlled Oscillator) type outputting a periodical signal S_1 with a frequency f_1, for example a sinusoidal signal with an oscillation frequency equal to f_1. The frequency f_1 value is controlled by a voltage applied to a control input **108** of the oscillator **106**. In order to lock and stabilize the oscillation frequency f_1 of the signal S_1, the oscillator **106** is regulated within a phase-locked loop (PLL). This PLL includes a first frequency divider **110** able to divide the frequency f_1 of the signal S_1 by an integer or fractional number N_1 higher than 1. A periodical signal with a frequency $f_2=f_1/N_1$ is thus obtained at the output of the first frequency divider **110**. This periodical signal with the frequency f_2 is sent at the input of a second frequency divider **112** able to divide the frequency f_2 by an integer or fractional number N_2 higher than 1. At the output of the second frequency divider **112**, a periodical signal with the frequency $f_1/(N_1 \cdot N_2)$ is thus obtained, which is compared to another very stable reference periodical signal with a frequency f_{ref}, for example provided by a quartz resonator. The total division factor $(N_1 \cdot N_2)$ is chosen such that the frequency $f_1/(N_1 \cdot N_2)$ is close to the frequency f_{ref} which is for example equal to 25 MHz, the factor $N_1 \cdot N_2$ being for example equal to about 2 400. A comparison between both these signals is made by a phase comparator **114** (PFD for <<Phase Frequency Detector>>) generating output signals proportional to the phase difference measured between both these signals, the values of which are positive or negative depending on the sign of the difference $f_1/(N_1 \cdot N_2)-f_{ref}$. These output signals are sent at the input of a charge pump circuit **116** and then of a low-pass filter **118** outputting the signal applied to the controlling input **108** of the oscillator **106** in order to adjust the oscillation frequency f_1, such that $f_1/(N_1 \cdot N_2)=f_{ref}$. The frequency-stable periodical signals with the frequencies f_1 and f_2 are then sent on inputs of a frequency mixer **120** outputting the first periodical signal the frequency spectrum of which includes lines at the frequencies f_a and f_b, the values of which correspond to $f_a=f_1-f_2$ and $f_b=f_1+f_2$.

When the device **100** is intended to be used in an E-Band type transceiver device, the frequency f_a is for example equal to about 55 GHz and the frequency f_b equal to about 65 GHz. To obtain these frequencies, the PLL of the generator **102** is for example made such that the VCO **106** outputs a sinusoidal signal S_1 with the frequency f_1=60 GHz. By making the first frequency divider **110** such that N_1=12, the signal obtained at the output of the first frequency divider **110** corresponds to a sinusoidal signal with the frequency f_2=5 GHz. The frequency mixer **120** thus outputs the first periodical signal the frequency spectrum of which includes two main lines at the frequencies $f_a=f_1-f_2$=55 GHz and $f_b=f_1+f_2$=65 GHz.

According to a second exemplary embodiment, the generator **102** may correspond to two distinct PLLs the VCOs of which output the periodical signals with the frequencies f_1 and f_2, and a frequency mixer similar to the frequency mixer **120** previously described and receiving at the input the output signals of the VCO of both PLLs. A same reference signal with the frequency f_{ref} may be applied at the input of both PLLs such that the periodical signals with the frequencies f_1 and f_2 are in phase with each other.

FIG. **3** shows a third exemplary embodiment of the generator **102**.

As in the first exemplary embodiment of the generator **102** previously described in connection with FIG. **2**, the generator **102** includes the VCO **106** regulated by a PLL formed by the elements **110**, **112**, **114**, **116** and **118**. These elements enable the periodical signal S_1, for example a sinusoidal signal, which is frequency-stable with a frequency f_1 to be obtained. Alternatively, it is possible to replace the VCO **106** and PLL by any device or structure able to provide such a frequency-stable periodical signal S_1, corresponding for example to a single resonator device when such a resonator device can directly provide the signal S_1. The choice of the type of device or structure generating the periodical signal S_1 can in particular be made as a function of the desired frequency f_1. A resonator device alone can be sufficient if the frequency f_1 does not exceed a value belong which it can then be necessary to involve a PLL for generating the signal S_1, for example for a frequency f_1 lower than about 500 MHz.

The generator **102** further includes two generators of periodically repeated oscillations train (PROT) at the frequencies f_a and f_b.

Each PROT generator includes a VCO type oscillator **122.1**, **122.2** voltage controlled by a control signal $V_{ctrl\_122.1}$, $V_{ctrl\_122.2}$, and controlled power supply means **124.1**, **124.2** supplying power to the oscillator **122.1**, **122.2** and which are controlled by the signal S_1. In the example of FIG. **3**, this controlled power supply corresponds to a controlled current source operating as a switch periodically switching OFF (period $T_1=1/f_1$) the power supply to the oscillator **122.1**, **122.2**. This controlled current source may correspond to an MOS transistor including a gate to which the signal S_1 is applied.

Generally, these controlled power supply means **124.1**, **124.2** may include a switch connected to a power supply input of the oscillator **122.1**, **122.2** and able to be controlled by the periodical signal S_1.

The oscillators **122.1** and **122.2** are thus alternately switched ON and OFF by this switch, that is switching ON or OFF providing output signals by the oscillators **122.1** and **122.2**, successively at frequency f_1. The oscillators **122.1** and **122.2** are thus controlled by a same signal S_C corresponding to the currents generated by the current sources **124.1** and **124.2** (and thus to the supply voltages provided to the oscillators **122.1** and **122.2**) and the wave form of which substantially corresponds to a positive square signal with the frequency f_1 (this square signal is not perfect and may have a trapezoidal shape, as is the case of the signal S_C shown for example in FIG. **4**A).

Thus, when the switching signal S_C switches ON the oscillators **122.1** and **122.2**, signals S_{G1} and S_{G2} corresponding to PROT are created at the outputs of the oscillators **122.1** and **122.2**. A half-period $T_1/2$ (with $T_1=1/f_1$) later, the oscillators **122.1** and **122.2** are switched OFF and the oscillations are interrupted. The alternating ON and OFF states every half-period $T_1/2$ corresponds to the case where the signal S_C has a duty cycle equal to 0.5. The signal S_C shown in FIG. **4**A switches ON the oscillators **122.1** and **122.2** for a duration T_H which is equal, in this example, to $T_1/2$.

However, this duty cycle (equal to T_H/T_1) may be different from 0.5, and more generally between 0 and 1, the values 0 and 1 being excluded, the duration of the ON state may be higher or lower than that of the OFF state.

Thus, pulsed signals S_{G1} and S_{G2} are created at centre frequencies f_{OL1} and f_{OL2}, corresponding to the free oscillation frequencies of the oscillators **122.1** and **122.2**, with a repetition period equal to T_1. The signals S_{G1} and S_{G2} thus correspond to PROT, that is herein trains of oscillations with the frequency f_{OL1} and f_{OL2}, with a duration lower than $T_1=1/f_1$ and periodically repeated with a repetition period equal to T_1.

The signals S_{G1} and S_{G2} thus periodically have a zero value over part of each period T_1, this part of each period T_1 approximately corresponding to the part of each period T_1 during which the signal S_C has a zero value. The feature of the signals S_{G1} and S_{G2} is to have their phase-locked to that of the signal S_1 with the frequency f_1 provided by the oscillator **106** and have centre frequencies f_{OL1} and f_{OL2} which are substantially equal to integer multiples of f_1 ($f_{OL1} \approx M_1 \cdot f_1$ and $f_{OL2}=M_2 \cdot f1$). This property is due to the fact that at the start of the oscillations, the oscillators **122.1** and **122.2** have a high elasticity and are easily locked to harmonics M_1 and M_2 of the frequency f_1 with M_1 and M_2

such that the products $M_1 \cdot f_1$ and $M_2 \cdot f_1$ are closest to the free oscillation frequencies f_{OL1} and f_{OL2} of the oscillators **122.1** and **122.2**. The M_1 and M_2 values, and thus those of the frequencies f_{OL1} and f_{OL2} depend on the values of the voltages $V_{ctrl\_122.1}$ and $V_{ctrl\_122.2}$ applied at the input of the oscillator **122.1** and **122.2**, these values of the voltages $V_{ctrl\_122.1}$ and $V_{ctrl\_122.2}$ being chosen such that $M_1 \cdot f_1 = f_a$ and $M_2 \cdot f_1 = f_b$.

The equivalent spectrum of each of the signals S_{G1} and S_{G2} has an envelope the shape of which corresponds to a cardinal sin, or sinc, the components of which are sinusoids with the centre frequency $M_1 \cdot f_1$ and $M_2 \cdot f_1$ respectively. The lines of the frequency spectra of S_{G1} and S_{G2} are spaced from each other by f_1. FIGS. **4**A and **4**B respectively show the wave form (time domain) and the spectrum (frequency domain) of the signal Sc. Likewise, FIGS. **5**A and **5**B respectively show the wave form and the spectrum of the signal S_{G1}. In FIG. **5**A, it can be seen that in each train of oscillations of the signal S_{G1}, the amplitudes of the oscillations are increasing upon starting the oscillator **114** and are decreasing upon stopping the oscillator **114**. Moreover, the oscillations of the trains of oscillations of S_{G1} are similar, in terms of phase, amplitude and frequency, from one train to the other. The frequency spectrum of the signal S_{G1} thus includes a main line at the frequency $f_a = M_1 \cdot f_1$, and secondary lines (having amplitudes lower than that of the main line) at other frequencies multiples of f_1. The wave form and the frequency spectrum of the signal S_{G2} are analogous to those of the signal S_{G1}, with a main line at the frequency $f_b = M_2 \cdot f_1$ and a free oscillation frequency $f_{OL2} \approx M_2 \cdot f_1 = f_b$.

From an analytical point of view, the signal S_{G1} is obtained by convoluting in the time domain between a windowed sinus, with the frequency f_{OL1} (corresponding to the free oscillation frequency of the oscillator **122.1**) and with a window width equal to T_H, with $T_H \in]0,T_1[$, and a Dirac comb with a period equal to T_1. The signal S_{G1} can thus be expressed as:

$$S_G(t) = \left[\sin(2\cdot\pi\cdot f_{OL}\cdot t)\cdot \prod_{T_H}(t)\right] \otimes \sum_{k=-\infty}^{\infty} \delta(t - k\cdot T_1)$$

$\Pi_{T_H}(t)$ is the windowing function corresponding to:

$$\prod_{T_H}(t) = \begin{cases} 0 & \forall\, t < 0 \\ 1 & \forall\, t \in]0, T_1[\\ 0 & \forall\, t > T_H \end{cases}$$

The frequency spectrum of the signal S_G corresponds in this case to:

$$|S_G(f)|_{f>0} = \left[\frac{1}{2}\delta(f - f_{OL}) \otimes T_H \cdot \mathrm{sinc}(\pi\cdot f\cdot T_H)\right]\cdot f_1 \cdot \sum_{k=-\infty}^{\infty} \delta(f - k\cdot f_1)$$

For each of the lines of frequencies f_j of the spectrum of the signal S_G (f_j being multiples of f_1), the amplitude A_j of each of these lines can be expressed by the equation:

$$A_j = \frac{1}{2}\sin c(\pi(f_j - f_{OL})\cdot T_H)$$

Analogous equations are applied for the signal S_{G2}, the term f_{OL1} used in the above equations being then replaced by the term f_{OL2}.

The signals S_{G1} and S_{G2} are then added by an adder **126** receiving at the input the signals S_{G1} and S_{G2} outputted by the oscillators **122.1** and **122.2**. FIG. **6** symbolically shows the addition of the frequency spectra of the signals S_{G1} and S_{G2} made by the adder **126**. The frequency spectrum of the signal obtained at the output of the adder **126** thus includes two main lines at the frequencies f_a and f_b corresponding to the main lines of the frequency spectra of the signals S_{G1} and S_{G2}. In the example of this figure, the frequencies f_a and f_b are consecutive integer multiples of f_1 such that $f_b = f_a + f_1$, and thus with $M_2 = M_1 + 1$, and the lines at the frequencies f_a and f_b are of the same amplitude. Because the signals S_{G1} and S_{G2} are generated from the same signal S_1, these signals thus have their phase coherent with each other.

In an alternative embodiment of the generator **102** described in connection with FIG. **3**, the oscillators **122.1** and **122.2** may be not controlled by a periodically interrupted supply source, but continuously supplied, providing sinusoidal signals with the frequencies f_{OL1} and f_{OL2}. These signals are then sent at the input of switches controlled by the periodical signal S_1. These switches are thus periodically (period T_1) in a closed position for a duration equal to T_H (for example equal to $T_1/2$ in the case of a duty cycle equal to 0.5) and in an open position for a duration equal to $T_1 - T_H$.

In this case, at the output of these switches, PROT type signals S_{G1} and S_{G2} are obtained, that is of the type train of oscillations with the frequency f_{OL1} or f_{OL2} periodically repeated with a repetition period equal to T_1. The oscillations of each of the trains of oscillations of S_{G1} and S_{G2} are thus not generally similar, in terms of phase, from one train to the other, but on the other hand the signals S_{G1} and S_{G2} are in phase with each other.

In this case, from an analytical point of view, the signal S_{G1} corresponds to the product of a sinus with the frequency f_{OL1} and a periodical square signal with the period T_1 and a duration in the high state T_H with $T_H \in]0,T_1[$ such that:

$$S_{G1}(t) = \sin(2\cdot\pi\cdot f_{OL1}\cdot t)\cdot\left[\prod_{T_H}(t) \otimes \sum_{k=-\infty}^{\infty} \delta(t - k\cdot T_1)\right]$$

The frequency spectrum of the signal S_{G1} corresponds in this case to:

$$|S_{G1}(f)|_{f>0} = \frac{1}{2}\delta(f - f_{OL1}) \otimes \left[T_H \cdot \mathrm{sinc}(\pi\cdot f\cdot T_H)\cdot f_1 \cdot \sum_{k=-\infty}^{\infty} \delta(f - k\cdot f_1)\right]$$

Analogous equations are applicable for the signal S_{G2}, the term f_{OL1} used in the equations above being then replaced by the term f_{OL2}.

FIG. **7** which schematically shows the switchable ILO **104** is now referred to. The switchable ILO **104** includes a resonating structure **130**, an electrical element **132** the electrical impedance of which is equivalent to that of a negative electrical resistance (that is at the terminals of which a voltage increases when the current flowing therethrough decreases, and conversely at the terminals of which a voltage decreases when the current flowing therethrough increases), and an injection circuit **134** to receive at the input the first periodical signal to which the switchable ILO **104** is intended to be locked.

The resonating structure **130** can be configured into two states: a first state such that the value of the free oscillation frequency of the switchable ILO **104** is equal or close to that of the frequency f_a, and a second state such that the value of the free oscillation frequency of the switchable ILO **104** is equal or close to that of the frequency f_b. Switching from one state to the other for the resonating structure **130** is made through a control signal applied at the input of the resonating structure **130**.

When no signal is applied to the input of the injection circuit **134**, the switchable ILO **104** oscillates at the free oscillation frequency the value of which depends on the state in which the resonating structure **130** is. When a signal with a sufficient amplitude and a frequency close to the free oscillation frequency of the switchable ILO **104** is applied at the input of the injection circuit **134**, the switchable ILO **104** is then locked to this signal and the frequency of the signal outputted by the switchable ILO **104** does not correspond to its free oscillation frequency but is equal to the frequency of the signal applied at the input of the injection circuit **134**.

As shown in FIG. **8**, the locking range of the switchable ILO **104** has a shape approximating a "V" the tip, or end of which is located at the free oscillation frequency of the switchable ILO **104**. In this FIG. **8**, a first locking range **136** is shown for the case where the resonating structure **130** is in the first state (for which the free oscillation frequency is close or equal to f_a), and a second locking range **138** is shown for the case where the resonating structure **130** is in the second state (for which the free oscillation frequency is close or equal to f_b). These locking ranges indicate the minimum amplitude value of the signal applied at the input of the injection circuit **134**, as a function of the frequency of this signal, for which the switchable ILO **104** is locked and outputs in this case a signal with a frequency equal to that of the signal applied at the input of the injection circuit **134**. The required amplitude for locking the switchable ILO **104** is reduced as the frequency of the signal applied at the input of the injection circuit **134** is close to the free oscillation frequency of the ILO **104**, and thus close to f_a when the resonating structure is in the first state and close to f_b when the resonating structure is in the second state.

FIG. **9** schematically shows an exemplary embodiment of the switchable ILO **104**. The resonating structure **130** includes an inductor **140** coupled in parallel with a first capacitor **142** and a second capacitor **144**. The value of the electric capacitance of the first capacitor **142** is different from that of the second capacitor **144**.

The resonating structure **130** also includes two switches **146** operating complementarily with respect to each other (one of both switches being in a closed position when the other of both switches is in an open position). The switches **146** are controlled by the control signal applied at the input of the resonating structure **130**. Thus, the resonating structure **130** forms an LC resonating circuit which includes, in the first state, the inductor **140** and the first capacitor **142**, and in the second state, the inductor **140** and the second capacitor **144**. The LC resonating structure formed by the resonating structure **130** thus includes the first capacitor **142** or the second capacitor **144** depending on the value of the control signal applied at the input of the resonating structure **130**, and the free oscillation frequency of the switchable ILO **104** is thus modified depending on the elements forming this LC resonating circuit.

Alternatively, the resonating structure **130** may include a single capacitor coupled to a first inductor in the first state and to a second inductor in the second state, the values of both these inductors being different.

In another alternative, it is also possible that the resonating structure **130** includes a first and a second inductor with different values, and a first and a second capacitor having different capacitance values, the first inductor being electrically coupled to the first capacitor in the first state, and the second inductor being electrically coupled to the second capacitor in the second state.

The electrical element **132** corresponds to an MOS type differential twisted pair, here formed by two NMOS transistors at which an output **148** of the switchable ILO **104** is located.

The injection circuit **134** includes a DC current blocking capacitance **150** coupled to a resistor **152**. The first periodical signal is intended to be applied to a first terminal of the capacitance **150**. A bias voltage, defining the bias current of the element **132**, is applied to a first terminal of the resistor **152**, and a second terminal of the resistor **152** is connected to a second terminal of the capacitance **150** and to the gate of a third NMOS transistor **154**. The drain of the third NMOS transistor **154** is connected to the electrical element **132**.

Alternatively, the third NMOS transistor **154** may have its source and drain connected in parallel to the resonating structure **130**.

According to another alternative, the injection circuit **134** may include, instead of the third NMOS transistor **154**, two MOS transistors the drains of which are connected to the drains of two MOS transistors of the electrical element **132** and the sources of which are connected to a bias current source. In this alternative, the injection circuit **134** also includes the capacitance **150** coupled to the resistor **152** analogously to the configuration previously described in connection with FIG. **9**. The first periodical signal is intended to be applied to the first terminal of the capacitance **150** and a bias voltage is intended to be applied to the first terminal of the resistor **152**, the second terminal of the resistor **152** being connected to the second terminal of the capacitance **150** and to the gates of two MOS transistors of the injection circuit **134** (the first periodical signal being in this case a differential signal).

The values of the inductor **140** and the electrical capacitances of the first capacitor **142** and the second capacitor **144** are chosen such that the free oscillation frequency of the switchable ILO **104** in the first state (first capacitor **142** coupled to the inductor **140**) is close or equal to f_a, and such that the free oscillation frequency of the switchable ILO **104** in a second state (second capacitor **144** coupled to the inductor **140**) is close or equal to f_b.

Thus, the switchable ILO **104** which receives at the input the first periodical signal including two main lines at the frequencies f_a and f_b outputs a frequency-stable periodical signal and with a frequency f_a or f_b depending on the state in which the resonating structure **130** is. The frequency of the output signal of the switchable ILO **104** can be easily and quickly switched between f_a and f_b by changing the state in which the resonating structure **130** is. The switchable ILO **104** behaves as a very selective band-pass filter through the locking made to the frequency f_a or f_b.

FIG. **10** shows a device **200** for generating two frequency-stable signals and the values of the frequencies of which can be modified, according to a second embodiment.

As for the previously described device **100**, the device **200** includes the generator **102** generating the first frequency-stable periodical signal the frequency spectrum of which includes two main lines at the frequencies f_a and f_b. This first periodical signal is sent to the inputs of two switchable ILOs **104.1** and **104.2**, for example similar to the previously described switchable ILO **104**. The switchable ILOs **104.1** and **104.2** are controlled such that they can be in two configurations:

- in a first configuration, the first switchable ILO **104.1** is locked to the frequency f_a and thus outputs a frequency-stable periodical signal and the frequency spectrum of which includes a single main line centred on f_a, and the second switchable ILO **104.2** is locked to the frequency f_b and thus outputs another frequency-stable periodical signal and the frequency spectrum of which includes a single main line centred on f_b;
- in a second configuration, the first switchable ILO **104.1** is locked to the frequency f_b and thus outputs a frequency-stable periodical signal and the frequency spectrum of which includes a single main line centred on f_b, and the second switchable ILO **104.2** is locked to the frequency f_a and thus outputs another frequency-stable periodical signal and the frequency spectrum of which includes a single main line centred on f_a.

Thus, regardless of the configuration of the switchable ILOs **104.1** and **104.2**, the frequencies at which the main lines of the frequency spectra of the signals obtained at the output of the switchable ILOs **104.1** and **104.2** are located are always different from each other, one being equal to f_a and the other being equal to f_b. Such a device **200** is thus well suitable for being used in a transceiver device simultaneously performing transmission and reception of signals in two distinct frequency bands that can be switched over.

In an alternative embodiment of the device **200** shown in FIG. **11**, the configurations according to which the switchable ILOs **104.1** and **104.2** are controlled may be such that:

- in a first configuration, the first switchable ILO **104.1** and the second switchable ILO **104.2** are locked to the frequency f_a and thus output the frequency-stable periodical signals and the frequency spectra of which include a single main line centred on f_a;
- in a second configuration, the first switchable ILO **104.1** and the second switchable ILO **104.2** are locked to the frequency f_b and thus output frequency-stable periodical signals and the frequency spectra of which include a single main line centred on f_b.

In the previously described devices **100** and **200**, the frequency spectrum of the first periodical signal generated by the generator **102** includes two main lines at the frequencies f_a and f_b, and the switchable ILO(s) enable(s) frequency-stable periodical signals and with a frequency corresponding to one of both frequencies f_a and f_b at which these main lines are located to be outputted. Alternatively, the frequency spectrum of the first periodical signal generated by the generator **102** may include n main lines located at n distinct frequencies, the generator **102** involving in this case several PLL or oscillators and frequency mixers. In this case, the device may include a higher number of switchable ILOs each able to be locked to at least two of said n frequencies depending on the state in which the switchable ILO is, to output a higher number of frequency-stable output signals and/or the ILO(s) of which is (are) able to be locked to more than two frequencies in order to obtain at the output one or more stable periodical signals the frequency of which can assume more than two values.

FIG. **12** shows a device **300** in which the signal outputted by the generator **102** includes three main lines at the frequencies f_a, f_b and f_c, and three switchable ILOs **104.1**, **104.2** and **104.3** each able to be locked to one of the three frequencies f_a, f_b and f_c (for example via using three capacitances with different values in the resonating structures of these switchable ILOs). The frequencies obtained on the three outputs of the switchable ILOs **104.1**, **104.2** and **104.3** may be different from each other (a signal of each of the three frequencies f_a, f_b and f_c on the three outputs) or at least partly similar (for example one of the output signals to one of the three frequencies f_a, f_b and f_c and both other output signals to one of both other frequencies, or the three output signals at the same frequency f_a, f_b or f_c).

In each of the devices **100**, **200** and **300**, the outputs of the switchable ILOs **104** may be connected in series to one or more other switchable ILOs in order to improve the spectral purity of the signals obtained at the output of these devices. Indeed, the output signal of such a switchable ILO is mainly comprised of the line to which the switchable ILO is locked, but the rejection of the lines adjacent to the main line is not infinite. The signal obtained at the output of the switchable ILO **104** may correspond not to a pure sinusoidal signal, but to a periodical signal the envelope of which is never zero and the frequency spectrum of which has a main line at the frequency to which the switchable ILO is locked. The secondary lines of this frequency spectrum, located at frequencies multiples of f_1, have amplitudes lower than that of the main line of this frequency spectrum. Adding one or more switchable ILOs in series enable these secondary lines to be attenuated or eliminated.

FIG. **13** shows another alternative of the device **200** previously described in connection with FIG. **10**. In this device **200**, each of the switchable ILOs **104.1** and **104.2** is connected in series with another switchable ILO **104.4** and **104.5** for example similar to the switchable ILO to which it is connected. The switchable ILO **104.4** is configured in the same locking state as that of the switchable ILO **104.1** (for example to the frequency f_a) and the switchable ILO **104.5** is configured in the same locking state as that of the switchable ILO **104.2** (for example at the frequency f_b). FIG. **14**A shows the spectra of the signals applied at the inputs of the switchable ILOs **104.1** and **104.2**, and include two main lines at the frequencies f_a and f_b. The locking ranges of the switchable ILOs **104.1** and **104.2** are also symbolically shown in this figure. FIG. **14**B shows the spectra of the signals obtained at the outputs of the switchable ILOs **104.1** and **104.2** and applied at the inputs of the switchable ILOs **104.4** and **104.5**. It can be seen in this FIG. **14**B that lines with low amplitudes are still present at the frequencies to which the switchable ILOs **104.1** and **104.2** were not locked. The locking ranges of the switchable ILOs **104.4** and **104.5** are also symbolically shown in this FIG. **14**B. Finally, FIG. **14**C shows the spectra of the signals obtained at the outputs of the switchable ILOs **104.4** and **104.5**. It can be seen in this FIG. **14**C that the lines with low amplitudes which were still present at the frequencies to which the switchable ILOs **104.1** and **104.2** were not locked (FIG. **14**B) have disappeared by virtue of the finer "filtering" made via the switchable ILOs **104.4** and **104.5**.

FIG. **15** schematically shows part of an FDD type transceiver device **1000** suitable for the E-Band communication standard and simultaneously operating in transmission and reception in two different frequency bands with a width equal to about 5 GHz and centred about the frequencies 70 GHz and 80 GHz. The device **1000** includes elements used for a signal transmission such as a baseband processing circuit **1002** receiving at the input the information to be transmitted, a modulator **1004**, a power amplifier **1006** and a transmitting antenna **1008**. The device **200** is for example used with the modulator **1004** in order to modulate the signal at the desired carrier frequency (about the frequency f_2 for example). The transmission system **1000** also includes elements used for a signal reception: a receiving antenna **1010**, a low noise amplifier **1012**, a demodulator **1014** and a baseband processing circuit **1016**. The device **200** is also used with the demodulator **1014** in order to demodulate the signal received (about the frequency f_b for example) in baseband. The transmission and reception frequency bands can be easily switched changing the state in which the device **200** is configured.

The previously described device for generating frequency-stable signals may also be used within any transceiver device type involving several frequency-stable signals and with different frequencies and which require to quickly modify these frequencies, for example multi-standard transceiver devices.

The previously described device for generating frequency-stable signals may also be used within an electro-optical transceiver device able to send data via Wavelength Division Multiplexing (WDM), that is by modulating several wavelengths sent via a same optical wave guide. The previously described device for generating frequency-stable signals can in this case be used to extract each wavelength of the signal including the different multiplexed wavelength and route these different signals with different wavelengths towards different outputs. The device for generating frequency-stable signals enables in this case the paths on which the different signals with different wavelengths are routed to be easily and quickly modified.

The use of a switchable injection-locked oscillator for generating a frequency-stable signal is also advantageous in a transmitting and receiving device **2000** able to perform transmission and reception of signals in two RF transmission frequency bands, for example of the E-band type (transmission in the bands 71-76 GHz and 81-86 GHz), and performing frequency translations using m channels enabling each of these RF bands to be divided into m frequency sub-bands, m being an integer number higher than 1, such as schematically shown in FIG. **16**.

The device **2000** includes an antenna **2002** for transmitting and receiving data. In the example described here, the frequencies of the transmission frequency band used for transmitting data, symbolically shown with the reference **2004**, are lower than those of the transmission frequency band used for receiving data, symbolically shown with the reference **2006**. The low frequency band **2004** used for transmitting data for example corresponds to the band 71-76 GHz, and the high frequency band **2006** used for receiving data for example corresponds to the band 81-86 GHz. Alternatively, the low frequency band **2004** could be used for receiving data and the high frequency band **2006** for transmitting data. The device **2000** also includes an element **2008** enabling the antenna **2002** to operate together with the transmitting elements and receiving elements of the device **2000**.

When a signal is received by the antenna **2002**, it is sent, via the element **2008**, at the input of a Low Noise Amplifier (LNA) **2010**, and then translated in an intermediate frequency band **2012** by a mixer **2014** receiving at the input the signal received and a stable periodical signal with the frequency f_{LO_IF1}, called S_{LO_IF1}.

The width of the high frequency band **2006** corresponds to that of the intermediate frequency band **2012**. Several analog-digital converters are used to convert the signals located in the different channels of this frequency band. This wide frequency band **2012** is frequency-demultiplexed in order to obtain m less wide frequency sub-bands distributed on m channels each comprising an analog-digital converter enabling the signals transmitted in the different channels of the band **2006** to be retrieved.

This demultiplexing is made on the m channels via a second frequency translation of m parts of the intermediate frequency band **2012** to m lower intermediate frequency bands, or directly in baseband (directly in baseband in the example shown in FIG. **16**). In FIG. **16**, this demultiplexing or second frequency translation, is made via m mixers **2016.1-2016.*m*** each receiving at the input the signal in the intermediate frequency band **2012** and a stable periodical signal with a centre frequency suitable for the part of the intermediate frequency band **2012** to be recovered and translated in baseband. Each of the mixers **2016.1-2016.*m*** thus receives at the input, in addition to the intermediate frequency signal, a stable periodical signal with a different frequency for each channel, herein with the frequencies F_{LO_CH1} to F_{LO_CHm}, these signals being called S_{LO_CH1} to S_{LO_CHm}. The signals in baseband obtained at the output of the mixers **2016.1-2016.*m*** are then individually filtered by band-pass filters **2018.1-2018.*m***, and then digitally converted by analog-digital converters **2020.1-2020.*m***, and outputted on the channels CH**1** to CHm.

To perform a signal transmission, reverse operations to those made during the previously described reception are implemented. Thus, the signals in baseband of the channels CH**1** to CHm are first individually converted by digital-analog converters **2022.1-2022.*m***, then individually filtered by band-pass filters **2024.1-2024.*m***, and translated in the intermediate frequency band **2012** via multiplexing in the frequency domain made by mixers **2026.1-2026.*m*** each receiving at the input one of the filtered analog signals and one of the signals S_{LO_CH1} to S_{LO_CHm}. The thus combined signals located in the intermediate frequency band **2012** form a single signal distributed on the intermediate frequency band **2012**. A translation in the frequency band **2004** is then made by a mixer **2028** receiving at the input the signal in the intermediate frequency band **2012** as well as a signal with the frequency f_{LO_IF2}, called S_{LO_IF2}. The output signal of the mixer **2028** is finally amplified by a power amplifier **2030** and then transmitted by the antenna **2002**.

The different channels CH**1** to CHm operate simultaneously or not upon transmitting or receiving data.

In an FDD type transmitting and receiving device, the intermediate frequency bands used upon transmitting and receiving are similar.

FIG. **17** shows two examples of channel distribution in the low transmission frequency bands 71-76 GHz.

It can be seen in this figure a first example in which two channels CH**1** and CH**2** having the references **10** and **12**, each with a width equal to 2 GHz, are used in the band 71-76 GHz. By analogy with FIG. **16**, this first example corresponds to a configuration of the device **2000** wherein m=2. In this case, the first channel **10** has a centre frequency F_{c1}=72.125 GHz, and the second channel **12** has a centre frequency F_{c2}=74.625 GHz. A second example is also shown in which four channels CH**1** to CH**4** having the references **20**, **22**, **24** and **26**, each with a width equal to 1 GHz, are used (case of FIG. **16** in which m=4). In this case, the first channel **20** has a centre frequency F_{c1}=71.625 GHz, the second channel **22** has a centre frequency F_{c2}=72.625 GHz, the third channel **24** has a centre frequency F_{c3}=74.125 GHz, and the fourth channel **26** has a centre frequency F_{c4}=75.125 GHz. It can also be seen in this figure that in any case, guard bands of 125 MHz are present at the ends of the low transmission frequency band. A similar configuration of the channels is found in the high transmission frequency band 81-86 GHz.

Generating the signals S_{LO_CH1} to S_{LO_CHm} and the signals S_{LO_IF1} and S_{LO_IF2} is made using symmetries which exist between the centre frequencies of the different channels and between the transmission frequency bands **2004** and **2006**. Thus, in the two examples shown in FIG. **17**, it can be seen that the channel distribution in the band 71-76 GHz is symmetric about the frequency 73.375 GHz, called F_{CLA} (also in the band 81-86 GHZ about the frequency 83.375 GHz, called F_{CUA}). In addition, both high and low transmission frequency bands each have a centre frequency (73.5 GHz for the band 71-76 GHz and 83.5 GHz for the band 81-86 GHz) equally distinct from a symmetry frequency called F_{CA}, which is equal to 78.5 GHz for the bands 71-76 GHz and 81-86 GHz.

FIG. **18** illustrates the principle used for generating the signals S_{LO_CH1} to S_{LO_CHm} and the signals S_{LO_IF1} and S_{LO_IF2} as a function of the channel distributions in the high and low transmission-reception frequency bands.

In the example of FIG. **18**, two channels CH**1** and CH**2** having a width equal to 2 GHz are present in the low transmission frequency band **2004** (for example the band 71-76 GHz) and are symmetrically arranged in this band on either side of the frequency F_{CLA}. This configuration corresponds to the channels **10** and **12** previously described in connection with FIG. **17**. The distance between each of the centre frequency F_{c1} and F_{c2} of the channels CH**1** and CH**2** and the frequency F_{CLA} is called F_2.

Likewise, two channels CH**1** and CH**2** with the same width are present in the high transmission frequency band **2006** (for example the band 81-86 GHz) and are symmetrically arranged in this band on either side of the frequency F_{CUA}. The distance between the centre frequencies $F_{c1'}$ and $F_{c2'}$ of these channels and the frequency F_{CUA} also corresponds to F_2. Both frequencies F_{CLA} and F_{CUA} are at a same distance from the band symmetry frequency called F_{CA}, this distance being called F_1.

The frequency F_{LO_IF2} corresponds to the frequency enabling the translation between the intermediate frequency band **2012** and the low transmission frequency band **2004** to be made. The frequency F_{LO_IF1} corresponds to the frequency enabling the translation from the high transmission frequency band **2006** to the intermediate frequency band **2012** to be made. The distance between the frequency F_{LO_IF2} and the frequency F_{CLA}, called F_{IF}, is equal to that between the frequency F_{LO_IF1} and the frequency F_{CUA}.

The channels which are translated into the intermediate frequency band **2012** have a symmetry about the frequency F_{IF}. In the example of FIG. **18**, the channels CH**1** from the high and low transmission frequency bands **2004** and **2006** both have, after translation in the intermediate frequency band **2012**, a same centre frequency F_{CLB} and the channels CH**2** both have a same centre frequency F_{CUB}. The distance between F_{IF} and one of both these centre frequencies is the same as the previously identified distance F_2.

Switching between the intermediate frequency band **2012** and the baseband for the channels is made from the frequencies F_{LO_CH1} and F_{LO_CH2}. Both these frequencies are symmetric with respect to the frequency F_{IF}.

Analogous symmetries are present by considering that each of the channels CH**1** and CH**2** described in connection with FIG. **18** corresponds to a train of at least two channels.

The device **2000** thus includes a frequency synthesis device enabling the frequency-stable periodical signals S_{LO_IF1}, S_{LO_IF2}, and S_{LO_CH1} to S_{LO_CHm} in the previously described example to be simultaneously generated, with a minimum number of elements by virtue of the identified symmetries. This frequency synthesis device generates these signals by combining two frequency components, one enabling the centre of symmetry to be obtained and the other corresponding to the spacing between this centre and the desired frequencies. For this, the frequency synthesis device includes two parts, each based on a PLL, one enabling the signals with the frequencies F_{LO_IF1} and F_{LO_IF2} to be generated, and the other enabling the signals with the frequency F_{LO_CH1} to F_{LO_CHm} to be generated.

FIG. **19** shows such a frequency synthesis device **400** according to a first embodiment.

The device **400** includes a first PLL **402**. A very frequency-stable reference periodical signal, for example from a quartz resonator, with a frequency F_{ref}, is applied to a first input of a phase comparator **404** (PFD for "Phase Frequency Detector"). The output signals from the phase comparator **404** are sent at the input of a charge pump circuit **406** and then of a low pass filter **408**. The filter **408** outputs a signal applied at the input of an oscillator **410**, herein a VCO (Voltage Controlled Oscillator), for example made as differential twisted pairs (resonator coupled with a negative resistance) outputting a sinusoidal signal with the frequency F_A. This signal with the frequency F_A is used for generating signals with the frequencies F_{LO_IF1} and F_{LO_IF2}. This signal is applied at the input of a first frequency divider **412** making a frequency division by a factor N1 corresponding to a number higher than 1, and advantageously an integer number higher than 1. This first frequency divider **412** outputs a signal with a frequency $F_B=F_A/N1$ used for generating signals with the frequencies F_{LO_CH1} to F_{LO_CHm} (F_{LO_CH1} and F_{LO_CH2} in the example of FIG. **19**). This signal is further applied to a second frequency divider **414** making a frequency division by a factor N2 which corresponds to a number higher than 1, and advantageously an integer number higher than 1, and the output of which is connected to a second input of the phase comparator **404**. The factor N2 is such that $F_{ref}=F_B/N2=F_A(N1\cdot N2)$.

The device **400** includes a second PLL **416**. The reference signal with the frequency F_{ref} is applied to a first input of a second phase comparator **418**. The output signals of the second phase comparator **418** are sent at the input of a second charge pump circuit **420** and a second high pass filter **422**. The second filter **422** outputs a signal applied to the input of a second oscillator **424**, here a VCO, outputting a signal with the frequency F_1. This signal with the frequency F_1 is used for generating signals with the frequencies F_{LO_IF1} and F_{LO_IF2}. This signal is applied at the input of a third frequency divider **426** making a frequency division by a factor N3 which corresponds to a number higher than 1, and advantageously an integer number higher than 1. This third frequency divider **426** outputs a signal with the frequency $F_2=F_1/N3$ used for generating signals with the frequencies F_{LO_CH1} and F_{LO_CH2}. This signal is further applied at the input of a fourth frequency divider **428** making a frequency division by a factor N4 which corresponds to a number higher than 1, and advantageously an integer number higher than 1, and the output of which is connected to a second input of the second phase comparator **418**. The factor N4 is such that $F_{ref}=F_2/N4=F_1/(N3\cdot N4)$.

The oscillators **410** and **424** may be made as described in documents "A 60 GHz UWB impulse radio transmitter with integrated antenna in CMOS65 nm SOI technology" by A. Siligaris and al., Silicon Monolithic Integrated Circuits in RF Systems (SiRF), 2011 IEEE 11th Topical Meeting on, pp. 153-156, 17-19 Jan. 2011 and "A 17.5-to-20.94 GHz and 35-to-41.88 GHz PLL in 65 nm CMOS for wireless HD applications" by O. Richard and al., Solid-State Circuits Conference Digest of Technical Papers (ISSCC), 2010 IEEE International, pp. 252-253, 7-11 Feb. 2010.

The frequency dividers **412**, **414**, **426** and **428** may use different architectures depending on the value of the divided frequency. At high frequencies, the frequency dividers such as the dividers **412** and **414** use CML ("Current Mode Logic") or ILFD ("Injection-Locked Frequency Divider") type circuits. The frequency dividers operating at lower frequencies, for example close to 1 GHz, such as the dividers **426** and **428** use counter type purely digital architectures. If the dividers **426** and **428** operate at higher frequencies, these dividers include for example a first CML type division stage which reduces the frequency to divide, outputting for example a frequency in the order of 1 GHz, and then a second stage forming purely digital dividers. The circuits forming the frequency dividers may be programmable such that the values of the division factors are adjustable, depending on the intended frequencies F_A, F_B, F_1 and F_2.

The signals with the frequencies F_A and F_1 are applied at the input of a first element **430** making a non-linear operation between these signals and generating a multi-tone, or multifrequency first signal, from these signals. This first element **430** corresponds for example to a mixer making a multiplication of the input signals with the frequencies F_A and F_1. The first multi-tone signal obtained at the output of the first element **430** thus includes, in its frequency spectrum, a first main line at the frequency F_A-F_1 which corresponds to the frequency F_{LO_IF2}, and a second main line at the frequency F_A+F_1 which corresponds to the frequency F_{LO_IF1}. This first multi-tone signal is sent to the input of a first frequency recovering circuit **432** discarding frequencies other than the frequency F_{LO_IF2} and outputting the periodical signal with the frequency F_{LO_IF2}, and to the input of a second frequency recovering circuit **434** discarding frequencies other than the frequency F_{LO_IF1} and outputting the periodical signal with the frequency F_{LO_IF1}.

The signals with the frequencies F_B and F_2 are applied at the input of a second element **436** making a non-linear operation between these signals and generating a second multi-tone signal from these signals. This second element **436** corresponds for example to a mixer making a multiplication of the input signals with the frequencies F_B and F_2. The second multi-tone signal obtained at the output of the second element **436** thus includes, in its frequency spectrum, a first main line at the frequency F_B-F_2 which corresponds to the frequency F_{LO_CH1}, and a second main line at the frequency F_B+F_2 which corresponds to the frequency F_{LO_CH2}. This second multi-tone signal is sent to the input of a third frequency recovering circuit **438** discarding frequencies other than the frequency F_{LO_CH1} and outputting the signal with the frequency F_{LO_CH1}, and to the input of a fourth frequency recovering circuit **440** discarding frequencies other than the frequency F_{LO_CH2} and outputting the signal with the frequency F_{LO_CH2}.

The frequency recovering circuits **432**, **434**, **438** and **440** include switchable ILOs able to be locked to the desired frequency and to output the periodical signals with desired frequencies. A switchable ILO acts both as a very selective band-pass filter and as a signal regenerator, via the locking made to the desired frequency.

The frequency recovering circuits **432**, **434**, **438** and **440** each play the role of a band-pass filter with a very high selectivity, and may each correspond to a switchable ILO or several switchable ILO circuits arranged in cascade.

Thus, at the output of the device **400**, signals S_{LO_IF1}, S_{LO_IF2}, and S_{LO_CH1} to S_{LO_CHm} with a pure spectrum are obtained, that is including a single line at the desired frequency, the phase of which is locked to that of the reference signal with the frequency F_{ref}, all the other undesired components having been discarded outside the frequency spectra of these signals by the frequency recovering circuits **432**, **434**, **438** and **440**. However, the rejection of the lines adjacent to the main line is not infinite in practice.

Thus, the signals S_{LO_IF1}, S_{LO_IF2}, and S_{LO_CH1} to S_{LO_CHm} obtained at the output of the frequency recovering circuits **432**, **434**, **438** and **440** may correspond not to pure sinusoidal signals, but to periodical signals the frequency spectra of which each have a main line at the desired frequency as well as secondary lines located at frequencies multiples of that of the main line. It is possible to increase this rejection by connecting in cascade (that is in series) a switchable ILO with one or more ILOs, being switchable or not, and/or one or more band-pass filters to form each of the frequency recovering circuits **432**, **434**, **438** and **440**, and thus further attenuating the secondary lines from the frequency spectra of the signals obtained at the output of these circuits.

FIG. **20** shows an alternative embodiment of the first PLL **402**. In this alternative embodiment, the input of the second frequency divider **414** is not connected to the output of the first frequency divider **412**, but is connected to the output of the oscillator **410**. In this configuration, the frequencies F_A and F_B are such that $F_B=F_A/N1$ and $F_{ref}=F_A/N2=F_B\cdot N1/N2$.

FIG. **21** shows an alternative embodiment of the second PLL **416**. In this alternative embodiment, the input of the fourth frequency divider **428** is not connected to the output of the third frequency divider **426**, but is connected to the output of the oscillator **424**. In this configuration, the frequencies F_1 and F_2 are such that $F_2=F_1/N3$ and $F_{ref}=F_1/N4=F_2\cdot N3/N4$.

The components of the PLLs **402** and **416** are chosen and sized such that the frequencies F_A, F_B, F_1 and F_2 of the generated signals are suitable for the channels of the low and high transmission frequency bands used. Indeed, by considering the low transmission frequency band, the frequencies F_A and F_B are such that $F_{CLA}=F_A-F_1+F_{IF}$ and $F_{IF}=F_B=F_A/N1$. The frequency F_A is thus such that $F_A=N1\cdot(F_{CLA}+F_1)/(N1+1)$. By considering the high transmission frequency band, the frequencies F_A and F_B can also be characterized such that $F_{CUA}=F_A+F_1+F_{IF}$, with still $F_{IF}=F_B=F_A/N1$. The frequency F_A is thus also such that $F_A=N1\cdot(F_{CUA}-F_1)/(N1+1)$. The F_{CLA}, F_{CUA}, F_1 and F_2 values correspond to specifications coming from the channel configuration (number, width) used in the transmission and reception frequency bands. For example, in the case of an E-band type transmission with channels with a width equal to 1 GHz or 2 GHz (corresponding to the examples described in connection with FIG. **17**), these frequencies are F_{CLA}=73.375 GHz, F_{CUA}=83.375 GHz, F_1=5 GHz, and F_2=1.25 GHz.

Alternatively, it is possible that the device **400** includes, instead of the two PLLs **402** and **416**, a single PLL for generating the signals with the frequencies F_A, F_B, F_1 and F_2. Such a configuration is possible when the F_A, F_B, F_1 and F_2 values have a common divider other than 1.

The above principles are applicable when two channels are distributed in each of the transmission frequency bands, but also when more than two channels are distributed in each of these bands provided that their centre frequencies are symmetrically distributed inside each transmission frequency band. In this case, the second multi-tone signal obtained at the output of the second element **436** is used for generating more than two periodical signals having different frequencies.

FIG. **22** shows part of the device **400** in which the second multi-tone signal obtained from the periodical signals with the frequencies F_B and F_2 enable more than two periodical signals having different frequencies (four in the example of FIG. **22**) to be generated.

As in the previously described example, the signals with the frequencies F_B and F_2 are applied at the input of the second element **436** (here a mixer).

The second multi-tone signal obtained at the output of the second element **436** is applied at the input of two frequency recovering circuits **438** and **440** (here switchable ILOs) outputting the signals with the frequencies F_B-F_2 and F_B+F_2. The signal outputted from the third frequency recovering circuit **438** is applied at the input of a third element **442** (here a mixer) making a non-linear operation between the signal with the frequency F_B-F_2 and a periodical (for example sinusoidal signal) with the frequency F_3 and generating a third multi-tone signal the frequency spectrum of which includes two main lines with the frequencies $F_B-F_2-F_3$ and $F_B-F_2+F_3$. This third multi-tone signal is then applied at the input of a fifth frequency recovering circuit **444** (here a switchable ILO) discarding from the frequency spectrum the frequencies other than the frequency $F_B-F_2-F_3$ and outputting a periodical signal with the frequency $F_{LO\_CH1}=F_B-F_2-F_3$, as well at the input of a sixth frequency recovering circuit **446** discarding from the frequency spectrum frequencies other than the frequency $F_B-F_2+F_3$ and outputting a periodical signal with the frequency $F_{LO\_CH2}=F_B-F_2+F_3$. In parallel with this, the signal outputted from the fourth frequency recovering circuit **440** is applied at the input of a fourth element **448** (here a mixer) making a non-linear operation between the signal with the frequency F_B+F_2 and the signal with the frequency F_3 and generating a fourth multi-tone signal the frequency spectrum of which includes two main lines at the frequencies $F_B+F_2-F_3$ and $F_B+F_2+F_3$. This fourth multi-tone signal is then applied at the input of a seventh frequency recovering circuit **450** (here a switchable ILO) discarding from the frequency spectrum frequencies other than the frequency $F_B+F_2-F_3$ and outputting the signal with the frequency $F_{LO\_CH3}=F_B+F_2-F_3$, as well at the input of an eighth frequency recovering circuit **452** discarding from the frequency spectrum frequencies other than the frequency $F_B+F_2+F_3$ and outputting the signal with the frequency $F_{LO\_CH4}=F_B+F_2+F_3$. At least one of the frequency recovering circuits **438**, **440**, **444**, **446**, **450** and **452** is switchable ILO. The circuit(s) which is (are) not switchable ILOs may be non-switchable ILO or band-pass filters.

The F_3 value is chosen depending on the desired values of F_{LO_CH1} to F_{LO_CHm} frequencies.

If the frequency F_3 has a common divider with the frequencies F_1 and F_2, the periodical signal with the frequency F_3 may be generated from the second PLL **416** which includes in this case a further frequency divider **454** making a frequency division by a factor N5, as is the case in the exemplary embodiments of the second PLL **416** shown in FIGS. **23**A and **23**B. In the configuration shown in FIG. **23**A, the frequencies F_1, F_2 and F_3 are such that: $F_2=F_1/N3$, $F_3=F_2/N4$ and $F_{ref}=F_3/N5=F_2/(N4\cdot N5)=F_1/(N3\cdot N4\cdot N5)$. In the configuration shown in FIG. **23**B, the frequencies F_1, F_2 and F_3 are such that: $F_2=F_3/N3$, $F_3=F_1/N4$ and $F_{ref}=F_1/N5=F_2\cdot N3/N5=F_3\cdot N4/N5$.

It is also possible in this case that the device **400** includes a single PLL for generating the signals with the frequencies F_A, F_B, F_1, F_2 and F_3. Such a configuration is possible when the F_A, F_B, F_3, F_2 and F_3 values each have a common divider. Such a configuration is shown in FIG. **24**. In this configuration, the values of these frequencies are such that $F_B=F_A/N1$, $F_1=F_A/N2$, $F_2=F_A/N3$, $F_3=F_A/N4$, and $F_{ref}=F_A/N5$. Other configurations of the frequency dividers **412**, **414**, **426**, **428** and **454** are possible while only having a single PLL for generating these periodical signals.

If more than four periodical signals with different frequencies are intended to be generated for the frequency translation between the intermediate frequency band and the baseband (more than four channels in each band transmission frequency band), the signals obtained at the output of at least one part of the frequency recovering circuits **444**, **446**, **450** and **452** may be sent again at the input of one or more elements making non-linear operations in order to generate new multi-tone signals from which a greater number of periodical signals with different frequencies may be obtained at the output of other frequency recovering elements, based on the same principle as that described above in connection with FIG. **22**.

Generally, in the case of an E-band type device, the different components may be sized in different ways, in particular depending on the N1 value chosen. However, all the possible N1 values are not judicious because it must be taken into account that the frequency F_{IF} has to be preferably higher than the width of the transmission frequency band (5 GHz in the case of E-Band) by a factor between about 3 and 10 for making the device **400** more easily. This means that great N1 values can in this case be removed. Further, too low a N1 value generates frequencies F_A and F_B being close, which is less interesting. The table hereinbelow gives values for the frequencies F_A and F_B, as well as the ratio of the frequency F_B to the width of the intermediate frequency band (5 GHz in the example described here), for different N1 values, and for $F_A=N1\cdot(F_{CLA}+F_1)/(N1+1)$ with $F_{CLA}=73.375$ GHz and $F_1=5$ GHz.

N1	F_A (GHz)	F_B (GHz)	F_B/ BW(IF)
1	39.185	39.185	7.84
2	52.250	26.125	5.22
3	58.781	19.593	3.91
4	62.700	15.675	3.13
5	65.312	13.062	2.61
6	67.178	11.190	2.24
7	68.578	9.796	1.959

The N1 value may advantageously be chosen such that it is equal to 2, 3 or 4. For example, for N1=4, the values of the centre frequencies of the four channels CH**1** to CH**4** with a width equal to 1 GHz in each transmission frequency band and in the intermediate frequency band are given in the table hereinbelow. In baseband, the centre frequencies of the channels are equal to 0 in transmission and reception.

	CH1	CH2	CH3	CH4
Centre frequency in the intermediate frequency band (GHz)	13.925	14.925	16.425	17.425
Centre frequency in the low transmission frequency band (GHz)	71.625	72.625	74.125	75.125
Centre frequency in the high transmission frequency band (GHz)	81.625	82.625	84.125	85.125

Also in the case where N1=4, the values of the centre frequencies of both channels CH**1** and CH**2** with a width equal to 2 GHz are given hereinbelow in the intermediate frequency band and in the transmission frequency bands. In baseband, the centre frequencies of the channels are equal to 0 in transmission and reception.

	CH1	CH2
Centre frequency in the intermediate frequency band (GHz)	14.425	16.925
Centre frequency in the low transmission frequency band (GHz)	72.125	74.625
Centre frequency in the high transmission frequency band (GHz)	82.125	84.625

An exemplary embodiment of the device **400** as shown in FIG. **19** making a transmission in the bands 71-76 GHz and 81-86 GHz with channels with a width equal to 2 GHz (two channels in each transmission band) is described hereinbelow. The resonator generates a sinusoidal signal with the frequency F_{ref}=25 MHz. The oscillator **410** is a VCO generating the sinusoidal signal with the frequency F_A=62.7 GHz. The first frequency divider **412** makes a division by a factor N1=4 of the frequency F_A, thus outputting a sinusoidal signal with the frequency F_B=15.675 GHz. The second frequency divider **414** makes a frequency division by a factor N2=627, thus outputting a sinusoidal signal with a frequency equal to 25 MHz.

The second PLL **416** uses the same signal with the frequency F_{ref}=25 MHz as that used in the first PLL **402**. The second oscillator **424** is a VCO generating a sinusoidal signal with the frequency F_1=5 GHz. The third frequency divider **426** makes a division by a factor N3=4 of the frequency F_1, thus outputting a sinusoidal signal with the frequency F_2=1.25 GHz. The fourth frequency divider **428** makes a frequency division by a factor N4=50, thus outputting a sinusoidal signal with the frequency equal to 25 MHz.

The elements **430** and **436** are mixers. The output signals of these mixers are sent at the input of frequency recovering circuits **432**, **434**, **438** and **440** corresponding to switchable ILOs. The first frequency recovering circuit **432** outputs a substantially sinusoidal signal with the frequency F_{LO_IF2}=57.7 GHz. The second frequency recovering circuit **434** outputs a substantially sinusoidal signal with the frequency F_{LO_IF1}=67.7 GHz. The third frequency recovering circuit **438** outputs a substantially sinusoidal signal with the frequency F_{LO_CH1}=14.425 GHz. The fourth frequency recovering circuit **440** outputs a substantially sinusoidal signal with the frequency F_{LO_CH2}=16.925 GHz.

For making a device **400** performing the transmission in the bands 71-76 GHz and 81-86 GHz with channels having a width equal to 1 GHz (four channels in each transmission frequency band), all the elements described above are used and coupled to those previously described in connection with FIG. **22**. The third element **442** is a mixer receiving at the input the signal with the frequency equal 14.425 GHz as well as a sinusoidal signal with the frequency F_3=500 MHz, and the fourth element **448** is also a mixer receiving at the input the signal with the frequency equal to 16.925 GHz as well as the signal with the frequency F_3. The output signals from these mixers are sent at the input of other frequency recovering circuit **444**, **446**, **450** and **452** corresponding to switchable ILOs. The fifth frequency recovering circuit **444** outputs the substantially sinusoidal signal with the frequency F_{LO_CH1}=13.925 GHz. The sixth frequency recovering circuit **446** outputs a substantially sinusoidal signal with the frequency F_{LO_CH2}=14.925 GHz. The seventh frequency recovering circuit **450** outputs a substantially sinusoidal signal with the frequency F_{LO_CH3}=16.425 GHz. The eighth frequency recovering circuit **452** outputs a substantially sinusoidal signal with the frequency F_{LO_CH4}=17.425 GHz.

In the different previously described examples and embodiments, the frequency recovering elements **432** and **434** generating the signals with the frequencies F_{LO_IF2} and F_{LO_IF1} may correspond to switchable ILOs that can be locked to either of both frequencies of the multi-tone signal applied at the input of these elements, as a function of a control signal applied at the input of these switchable ILOs. Thus, it is possible to readily and quickly reverse the frequency bands used for transmitting and receiving data in the device **2000**, which is very advantageous in the case of the E-band type transmission device and other FDDs.

It is also possible that the selecting elements generating the signals S_{LO_CH1} correspond to switchable ILOs, that is include a mechanism enabling them to modify their locking range, and thus to be locked to one of the frequencies of the spectrum of the multi-tone signal according to the configuration in which each switchable ILO is. The signal obtained at the output of a switchable ILO is thus a frequency-stable periodical signal, for example a sinusoidal or substantially sinusoidal one, the frequency spectrum of which includes a single main line at the desired frequency according to the configuration in which the switchable ILO is put. This enables, from a frequency point of view, to invert the position of the channels if need be. When each transmission frequency band includes more than two channels, for example four channels, the use of switchable ILOs enable the number of components used for generating the signals S_{LO_CH1} to be reduced, as shown for example in FIG. **25**. Unlike the exemplary embodiment previously described in connection with FIG. **22** in which the output signal from the second element **436** is applied at the input of the third and fourth frequency recovering elements **438** and **440**, the output signal from the second element **436** applied at the input of another element **456**, for example a mixer, making a non-linear operation between the multi-tone signal including the frequencies F_B-F_2 and F_B+F_2 and the signal with the frequency F_3.

Thus, the multi-tone signal obtained at the output of the element **456** includes in its spectrum four main lines at the frequencies F_{LO_CH1}, that is the frequencies $F_B-F_2-F_3$, $F_B-F_2+F_3$, $F_B+F_2-F_3$ and $F_B+F_2+F_3$. This multi-tone signal is then applied to the input of four switchable ILOs **458**, **460**, **462** and **464** each able to be locked to one of these frequencies and output a substantially sinusoidal signal with a frequency equal to one of these four frequencies. All the frequency positions of the channels can be switched over with respect to each other depending on the values of the control signals applied to the control inputs of these switchable ILOs. It is also possible that a same frequency is selected by several of the switchable ILOs, for example in the case of a transmitter or receiver working on a single channel at a time which can be selected between the allocated channels in the band covered by the frequency generator.

In the different exemplary embodiments previously described, the multi-tone signals include main lines (corresponding to the frequencies to be recovered by the frequency recovering circuits) with amplitudes being similar and/or in phase with each other, which enables the generated periodical signals to have substantially constant amplitudes and/or phases regardless of the frequency to which each ILO is locked. The lines corresponding to the frequencies to be recovered being main lines of the frequency spectrum of the multi-tone signals (lines with a greater amplitude with respect to the neighbour lines) facilitates locking the ILOs to these lines and avoids locking to a possible other line of the frequency spectrum of these signals. The characteristic according to which the main lines have substantially similar amplitudes may correspond to a voltage difference of about 4 dB maximum between these amplitudes.

The use of switchable ILOs may also be contemplated for making variable frequency channels, as shown in FIG. **26**. In this figure, a single switchable ILO **458** is used because the device **2000** is intended to operate with a single channel the centre frequency of which can change. Thus, the frequency of the output signal outputted by this switchable ILO **458** may correspond to one of the four frequencies the multi-tone signal outputted by the element **456** includes.

FIG. **27** shows an exemplary embodiment of a frequency recovering circuit **490** enabling such signals to be outputted. The circuit **490** receives at the input the multi-tone signal including in its spectrum the frequency F_{LO_CH1} corresponding for example to one of both frequencies F_B-F_2 and F_B+F_2. The circuit **490** includes a first switchable ILO **492** the input of which receives the multi-tone signal and the output of which is connected to the input of an active or passive type phase shift element **494** enabling the signal applied at the input to be reproduced on one of its both outputs and the signal applied at the input phase shifted by 90° to be generated on the other of both its outputs. Each of both these signals is applied at the input of two other ILOs, being switchable or not, **496** and **498** outputting the signals $S_{LO\_CHi\_I}$ and $S_{LO\_CHi\_Q}$. Both ILOs **496** and **498** operate either independently of each other, or in a coupled way such that the outputs of both ILOs **496** and **498** are phase shifted from each other by 90° without involving the phase shift element **494**. The operation of such a Quadrature VCO (QVCO) type element is for example described in document "A 17.5-to-20.94 GHz and 35-to-41.88 GHz PLL in 65 nm CMOS for wireless HD applications" by O. Richard and al., Solid-States Circuits Conference Digest of Technical Papers (ISSCC), 2010 IEEE International, pages 252-253, 7-11 Feb. 2010.

The invention claimed is:

1. A device for generating at least one frequency-stable periodical signal, comprising:

a generator configured to generate at least one first periodical signal, a frequency spectrum of which includes at least two lines at different frequencies f_a and f_b provided simultaneously in the generated first periodical signal;

a first switchable injection-locked oscillator configured to receive, at a first input, the first periodical signal and to be locked, in a first state, to the frequency f_a, and in a second state, to the frequency f_b, as a function of a value of at least one control signal applied at a second input of the first switchable injection-locked oscillator.

2. The device according to claim **1**, comprising at least one of features:

lines at the frequencies f_a and f_b have substantially similar amplitudes;

lines at the frequencies f_a and f_b are in phase with each other;

lines at the frequencies f_a and f_b correspond to two main lines of the frequency spectrum of the first periodical signal.

3. The device according to claim **1**, wherein the first switchable injection-locked oscillator comprises:

a resonating structure configured to generate a second periodical signal oscillating, in the first state, at a first free oscillation frequency, and in the second state, at a second oscillation frequency with a value different from that of the first free oscillation frequency;

an electrical element electrically coupled to the resonating structure with an impedance equivalent to that of a negative electrical resistance;

an injection circuit electrically coupled to the electrical element, receiving at an input the first periodical signal and configured to provide the electrical element with a current having a frequency equal to that of the first periodical signal.

4. The device according to claim **3**, wherein the resonating structure of the first switchable injection-locked oscillator includes at least one LC resonating circuit comprising the following components:

an inductor coupled in parallel, in the first state, to a first capacitor or, in the second state, to a second capacitor having an electric capacitance with a value different from that of the first capacitor, or

a capacitor coupled in parallel, in the first state, to a first inductor or, in the second state, to a second inductor with a value different from that of the first inductor, or

in the first state, a first inductor coupled in parallel with a first capacitor or, in the second state, a second inductor coupled in parallel to a second capacitor, the first inductor having a value different from that of the second inductor and the first capacitor having an electric capacitance with a value different from that of the second capacitor,

and further comprises switching elements configured to modify couplings of the components of the LC resonating circuit as a function of the control signal.

5. The device according to claim **3**, wherein the electrical element of the first switchable injection-locked oscillator comprises an MOS type differential twisted pair.

6. The device according to claim **3**, wherein the injection circuit of the first switchable injection-locked oscillator comprises:

a capacitor including a first terminal to which the first periodical signal is configured to be applied;

a resistor including a first terminal to which a DC bias voltage is configured to be applied and a second terminal electrically connected to a second terminal of the capacitor;

an MOS transistor a gate of which is electrically connected to the second terminal of the capacitor and a drain of which is electrically connected to the electrical element of the switchable injection-locked oscillator.

7. The device according to claim **1**, wherein the generator comprises:

a phase-locked loop outputting a third periodical signal with a frequency f**1** and a fourth periodical signal with a frequency $f_2=f_1/N_1$, with N_1 higher than 1;

a frequency mixer receiving at an input the third periodical signal and the fourth periodical signal and outputting the first periodical signal such that $f_a=f_1-f_2$ and $f_b=f_1+f_2$.

8. The device according to claim **1**, wherein the generator comprises:

a phase-locked loop outputting a third periodical signal with a frequency f_1;

means to receive at an input the periodical signal with a frequency f_1 and to generate at least two signals S_{G1} and S_{G2} in phase with each other and each corresponding to a train of oscillations with a frequency substantially equal to f_a and f_b respectively, with a duration lower than $T_1=1/f_1$ and periodically repeated at the frequency f_1,

an adder configured to output the first periodical signal corresponding to the sum of the signals S_{G1} and S_{G2}.

9. The device according to claim **8**, wherein the means to receive of the generator includes at least two voltage controlled oscillators with free oscillation ranges that include the frequencies f_a and f_b respectively, and at least two switches connected at power supply inputs of the voltage controlled oscillators and configured to be controlled by the periodical signal with the frequency f_1 such that they generate supply non-zero voltages of the voltage controlled oscillators only for part of each period T_1 or at least two switches connected to outputs of the voltage controlled oscillators and configured to be controlled by the periodical signal with the frequency f_1 such that they break electrical connections between outputs of the voltage controlled oscillators and inputs of the adder for part of each period T_1.

10. The device according to claim **1**, further comprising at least one second switchable injection-locked oscillator configured to receive at an input the first periodical signal and to be locked in a first state to the frequency f_b and in a second state to the frequency f_a, or to be locked in the first state to the frequency f_a and in the second state to the frequency f_b, as a function of the control signal applied at the input of the first and second switchable injection-locked oscillators.

11. The device according to claim **1**, wherein the frequency spectrum of the first periodical signal includes at least n lines with n different frequencies, and further including n switchable injection-locked oscillators each configured to receive at an input the first periodical signal and to be locked to each of the n frequencies as a function of a value of the control signal applied the input of the n switchable injection-locked oscillators, n being an integer number higher than 1.

12. The device according to claim **1**, further comprising at least one third switchable injection-locked oscillator configured to receive at the input an output signal of the first or second switchable injection-locked oscillator or one of the n switchable injection-locked oscillators, and to be locked to a frequency similar to that to which the switchable injection-locked oscillator is locked to which the third switchable injection-locked oscillator is connected.

13. A device for transmitting and/or receiving signals, comprising at least one device for generating a frequency-stable periodical signal according to claim **1**, coupled to a modulator and/or a demodulator of the transmitting and/or receiving device.

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